

LM4050WG5.0RLQV Neutron Displacement Damage (NDD) Characterization



ABSTRACT

This report presents the effect of neutron displacement damage (NDD) on the LM4050WG5.0RLQV device. The devices were radiated up to 1×10^{13} n/cm² (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 LM4050WG5.0RLQV is a radiation-hardness-assured (RHA) 5.0-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 LM4050-5.0QML has a 74 μ 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	LM4050WG5.0RLQV
Device Function	Shunt Voltage Reference
Die Name	GLLM4050CLVF3E
Package	10-pin CFP (NAC)
Technology	LFAST
A/T Lot Number / Date Code	2027654 / H9C1049A
Unbiased Quantity Tested	9 + control
Exposure Facility	VPT Rad
Neutron Fluence (1-MeV equivalent)	1.0×10^{12} , 5.0×10^{12} , 1.0×10^{13} n/cm ²
Irradiation Temperature	25°C
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2 Test Procedures

The LM4050WG5.0RLQV 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 LM4050WG5.0RLQV.

Table 2-1. Neutron Irradiation Conditions

Group	Sample Qty	Neutron Fluence (n/cm ²)	Bias
A	3	1.0×10^{12}	Unbiased
B	3	5.0×10^{12}	Unbiased
C	3	1.0×10^{13}	Unbiased

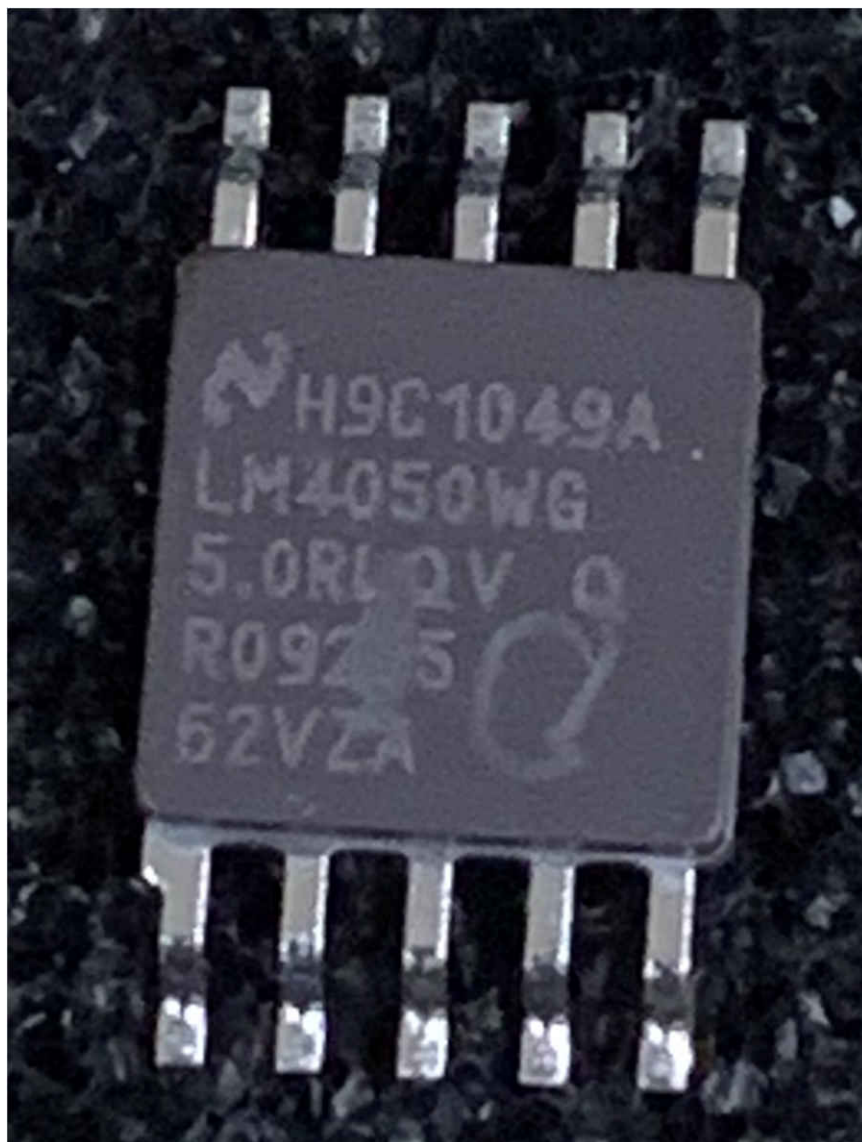


Figure 2-1. LM4050WG5.0RLQV Device

The LM4050WG5.0RLQV is packaged in a 10-pin 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/cm² (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/cm²-s. The maximum neutron fluence rate is approximately 1.0E11 n/cm²-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 1×10^{12} n/cm² level were marginal and only appeared in one device. At the 5×10^{12} n/cm² fluence levels, failures were present in all three devices. At the 1×10^{13} n/cm² 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			53	70	μA	3.1
Reverse Breakdown Voltage	I _R = 100 μA		5.0		V	4.2
Reverse Breakdown Voltage Tolerance	I _R = 74 μA			±5.0	mV	5.3
	I _R = 100 μA			±5.0		4.2
	I _R = 1 mA			±8		6.4
	I _R = 10 mA			±18		9.7
	I _R = 15 mA			±20		8.6

5 Revision History

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

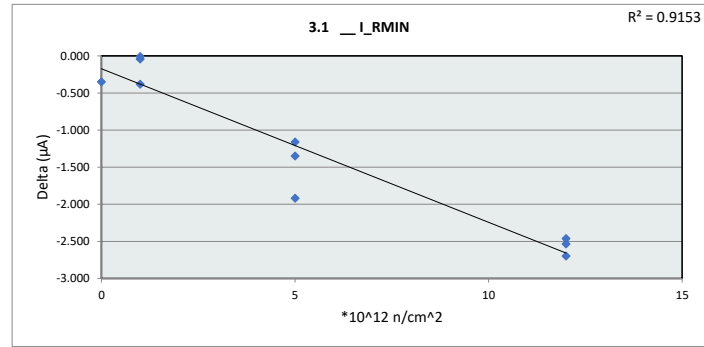
DATE	REVISION	NOTES
April 2022	*	Initial release

A Appendix: NDD Test Results

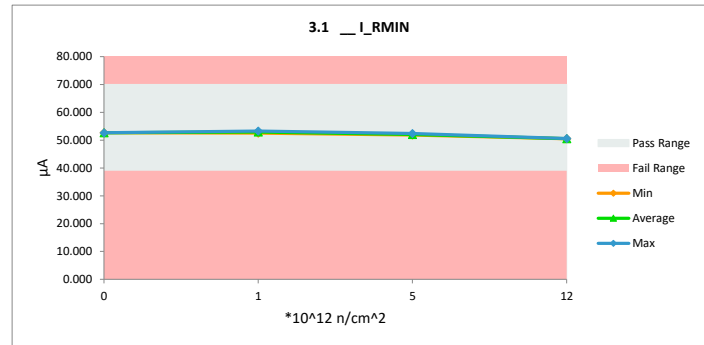
This appendix contains the detailed NDD test results.

NDD Report LM4050WG5.0RLQV

		3.1 __ I_RMIN		
Test Site				
Tester				
Test Number				
Unit		µA	µA	
Max Limit		70	70	
Min Limit		39	39	
*10 ¹² n/cm ²	Serial #	PRE	POST	Delta
1	1.1	52.892	52.510	-0.382
1	2.1	52.955	52.945	-0.010
1	3.1	53.309	53.267	-0.042
5	4.1	53.744	52.394	-1.350
5	5.1	53.726	51.806	-1.919
5	6.1	53.159	51.997	-1.161
12	7.1	53.275	50.577	-2.697
12	8.1	53.058	50.524	-2.534
12	9.1	52.958	50.496	-2.462
0	10.1	53.018	52.666	-0.351
Max		53.744	53.267	-0.010
Average		53.209	51.918	-1.291
Min		52.892	50.496	-2.697
Std Dev		0.309	1.043	1.066



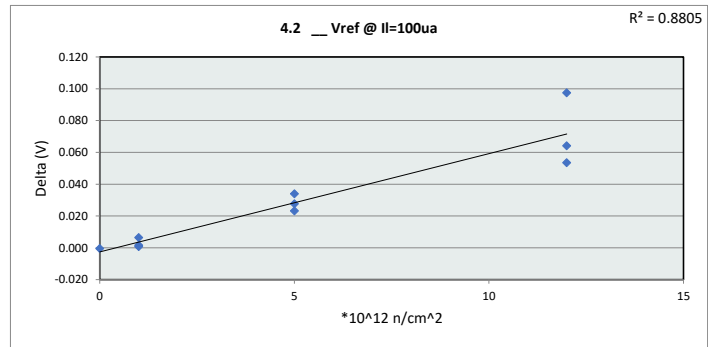
		3.1 __ I_RMIN			
Test Site					
Tester					
Test Number					
Max Limit		70	µA		
Min Limit		39	µA		
*10 ¹² n/cm ²		0	1	5	12
LL		39.000	39.000	39.000	39.000
Min		52.666	52.510	51.806	50.496
Average		52.666	52.907	52.066	50.532
Max		52.666	53.267	52.394	50.577
UL		70.000	70.000	70.000	70.000



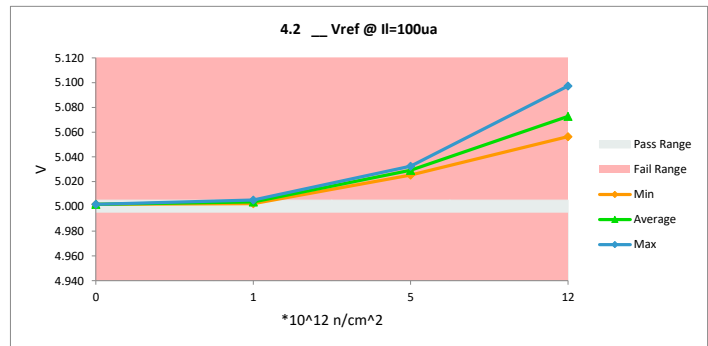
NDD Report LM4050WG5.0RLQV

4.2 __ Vref @ Il=100ua	
Test Site	
Tester	
Test Number	
Unit	V
Max Limit	5.005
Min Limit	4.995

*10 ¹² n/cm ²	Serial #	PRE	POST	Delta
1	1.1	5.003	5.003	0.001
1	2.1	4.999	5.005	0.006
1	3.1	5.001	5.002	0.002
5	4.1	4.999	5.032	0.034
5	5.1	5.002	5.025	0.023
5	6.1	5.002	5.030	0.028
12	7.1	5.000	5.097	0.097
12	8.1	5.000	5.064	0.064
12	9.1	5.003	5.056	0.053
0	10.1	5.002	5.002	-0.001
Max		5.003	5.097	0.097
Average		5.001	5.032	0.031
Min		4.999	5.002	-0.001
Std Dev		0.002	0.032	0.032



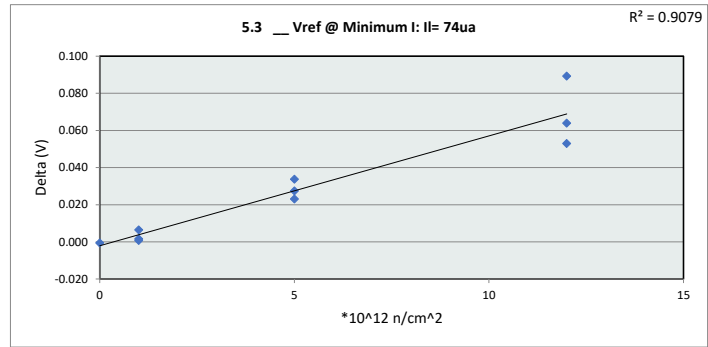
4.2 __ Vref @ Il=100ua					
Test Site					
Tester					
Test Number					
Max Limit	5.005	V			
Min Limit	4.995	V			
*10 ¹² n/cm ²	0	1	5	12	
LL	4.995	4.995	4.995	4.995	
Min	5.002	5.002	5.025	5.056	
Average	5.002	5.004	5.029	5.073	
Max	5.002	5.005	5.033	5.097	
UL	5.005	5.005	5.005	5.005	



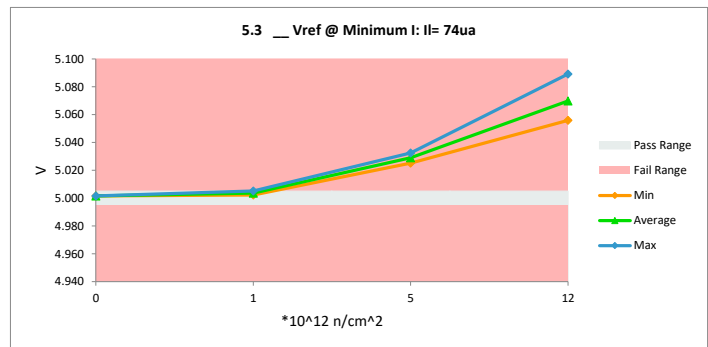
NDD Report LM4050WG5.0RLQV

5.3 __ Vref @ Minimum I: Il= 74	
Test Site	
Tester	
Test Number	
Unit	V
Max Limit	5.005
Min Limit	4.995

*10 ¹² n/cm ²	Serial #	PRE	POST	Delta
1	1.1	5.003	5.003	0.001
1	2.1	4.999	5.005	0.006
1	3.1	5.001	5.002	0.002
5	4.1	4.999	5.032	0.034
5	5.1	5.002	5.025	0.023
5	6.1	5.002	5.029	0.027
12	7.1	5.000	5.089	0.089
12	8.1	5.000	5.064	0.064
12	9.1	5.003	5.056	0.053
0	10.1	5.002	5.002	-0.001
Max		5.003	5.089	0.089
Average		5.001	5.031	0.030
Min		4.999	5.002	-0.001
Std Dev		0.002	0.030	0.031



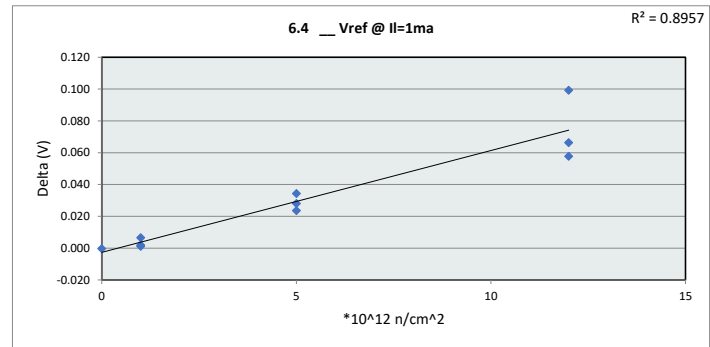
5.3 __ Vref @ Minimum I: Il=				
Test Site				
Tester				
Test Number				
Max Limit	5.005 V			
Min Limit	4.995 V			
*10 ¹² n/cm ²	0	1	5	12
LL	4.995	4.995	4.995	4.995
Min	5.002	5.002	5.025	5.056
Average	5.002	5.004	5.029	5.070
Max	5.002	5.005	5.032	5.089
UL	5.005	5.005	5.005	5.005



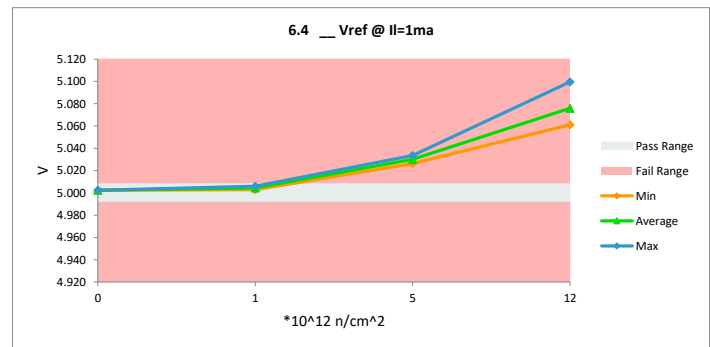
NDD Report LM4050WG5.0RLQV

6.4 __ Vref @ Il=1ma	
Test Site	
Tester	
Test Number	
Unit	V
Max Limit	5.008
Min Limit	4.992

*10 ¹² n/cm ²	Serial #	PRE	POST	Delta
1	1.1	5.003	5.004	0.001
1	2.1	4.999	5.006	0.007
1	3.1	5.001	5.003	0.002
5	4.1	4.999	5.034	0.034
5	5.1	5.003	5.026	0.024
5	6.1	5.002	5.030	0.028
12	7.1	5.000	5.100	0.099
12	8.1	5.001	5.067	0.066
12	9.1	5.003	5.061	0.058
0	10.1	5.003	5.002	0.000
Max		5.003	5.100	0.099
Average		5.001	5.033	0.032
Min		4.999	5.002	0.000
Std Dev		0.002	0.033	0.033



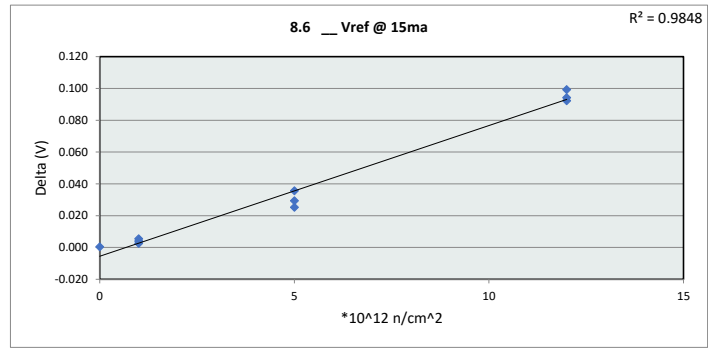
6.4 __ Vref @ Il=1ma					
Test Site					
Tester					
Test Number					
Max Limit	5.008	V			
Min Limit	4.992	V			
*10 ¹² n/cm ²	0	1	5	12	
LL	4.992	4.992	4.992	4.992	
Min	5.002	5.003	5.026	5.061	
Average	5.002	5.004	5.030	5.076	
Max	5.002	5.006	5.034	5.100	
UL	5.008	5.008	5.008	5.008	



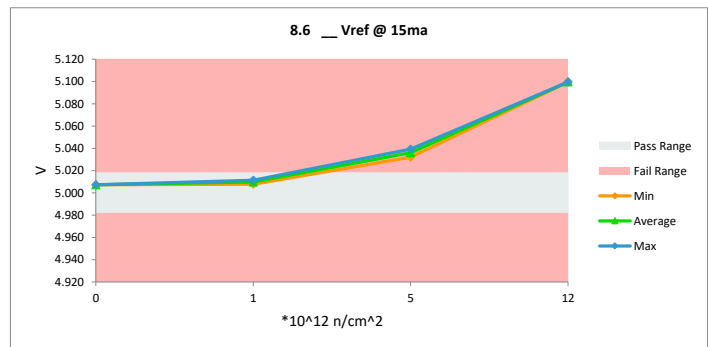
NDD Report LM4050WG5.0RLQV

8.6 __ Vref @ 15ma	
Test Site	
Tester	
Test Number	
Unit	V
Max Limit	5.018
Min Limit	4.982

*10 ¹² n/cm ²	Serial #	PRE	POST	Delta
1	1.1	5.007	5.011	0.004
1	2.1	5.005	5.010	0.005
1	3.1	5.005	5.008	0.003
5	4.1	5.004	5.039	0.036
5	5.1	5.007	5.032	0.025
5	6.1	5.007	5.036	0.029
12	7.1	5.000	5.100	0.099
12	8.1	5.005	5.100	0.094
12	9.1	5.007	5.100	0.092
0	10.1	5.007	5.007	0.000
Max		5.007	5.100	0.099
Average		5.005	5.044	0.039
Min		5.000	5.007	0.000
Std Dev		0.002	0.040	0.041



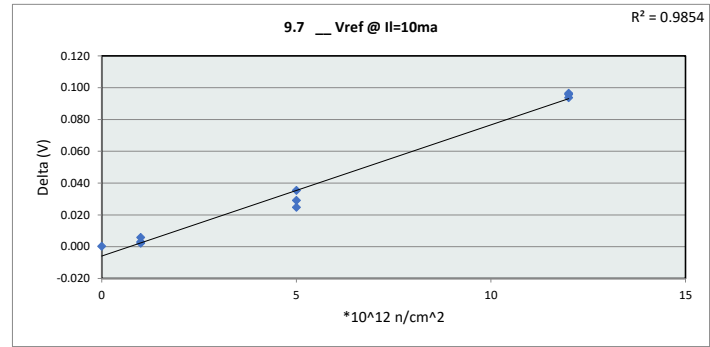
8.6 __ Vref @ 15ma					
Test Site					
Tester					
Test Number					
Max Limit	5.018	V			
Min Limit	4.982	V			
*10 ¹² n/cm ²	0	1	5	12	
LL	4.982	4.982	4.982	4.982	
Min	5.007	5.008	5.032	5.100	
Average	5.007	5.010	5.036	5.100	
Max	5.007	5.011	5.039	5.100	
UL	5.018	5.018	5.018	5.018	



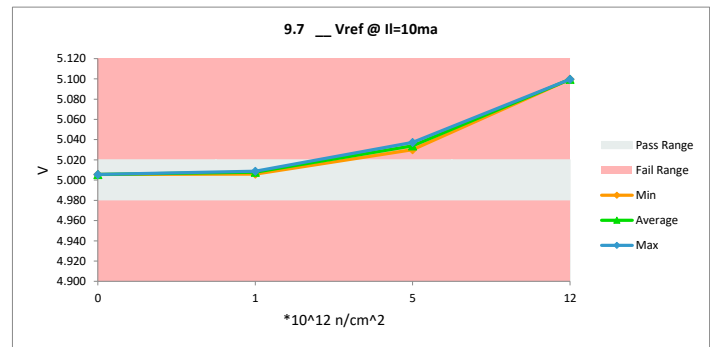
NDD Report LM4050WG5.0RLQV

9.7 __ Vref @ Il=10ma		
Test Site		
Tester		
Test Number		
Unit	V	V
Max Limit	5.02	5.02
Min Limit	4.98	4.98

*10 ¹² n/cm ²	Serial #	PRE	POST	Delta
1	1.1	5.006	5.009	0.003
1	2.1	5.003	5.009	0.006
1	3.1	5.004	5.006	0.002
5	4.1	5.002	5.037	0.035
5	5.1	5.005	5.030	0.025
5	6.1	5.005	5.034	0.029
12	7.1	5.003	5.100	0.097
12	8.1	5.004	5.100	0.096
12	9.1	5.006	5.100	0.094
0	10.1	5.005	5.006	0.000
Max		5.006	5.100	0.097
Average		5.004	5.043	0.039
Min		5.002	5.006	0.000
Std Dev		0.001	0.041	0.041



9.7 __ Vref @ Il=10ma				
Test Site				
Tester				
Test Number				
Max Limit	5.02	V		
Min Limit	4.98	V		
*10 ¹² n/cm ²	0	1	5	12
LL	4.980	4.980	4.980	4.980
Min	5.006	5.006	5.030	5.100
Average	5.006	5.008	5.034	5.100
Max	5.006	5.009	5.037	5.100
UL	5.020	5.020	5.020	5.020



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