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RADIATION TEST REPORT FOR NATIONAL SEMICONDUCTORS LM139A (DATE CODE 0121)

PROJECT SMART1

prepared by/*préparé par*	A. Mohammadzadeh (TOS-QCA), B. Nickson (TOS-QCA), P. Collins (TOS-QCL)

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ESTEC

Keplerlaan 1 - 2201 AZ Noordwijk - The Netherlands

Tel. (31) 71 5656565- Fax (31) 71 5656040

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Test Report Number	ESA-QCA-RTR-LM139-00102
Project	SMART1
SCC Component no.	LM139a
Component Designation	Quad Bipolar Voltage Comparator (LM139AWG/883, H0D0121A)
Irradiation Spec. no.	
Family	Integrated Circuits
Group	Silicon Monolithic
Package	Ceramic
Component Specification	
Test House Name	ESA / ESTEC
Irradiation Test Plan Number	ESA-QCA-RTP-LM139-00102
Manufacturer name	National Semiconductors
Application type of Acceptance	
Serial Number of samples	Six (6) samples serialised as Ref, 1, 2, 3, 4 and 5
Manufacturing Date Code	
Irradiation Measurement Interval: Biased Unbiased: Circuit Reference: Supply Voltage: Temp ^{o}C: Duration:	 Yes No Two devices at +20V and two devices at +12V Rom temperature 20 ± 3
Electrical Measurement Parameters	See section 3.1
Facility Source: Energy: Dose Rate: Absorbed Material: Thickness: Temperature ^{o}C:	 ^{60}Co 48 rad/min and 0.8 rad/min N/A N/A 20 ± 3
Dosimetry / Calibration method.	A calibrated NE2571, 0.66cc air ionisation chamber read by a calibrated Farmer 2670 dosimeter.
Anneal Test Biased Unbiased Bias Circuit Reference Supply Voltage Duration	 Not available

1 INTRODUCTION

The following document contains the Radiation Test Report for LM139 quad voltage comparator for the SMART1 project.

2 APPLICABLE DOCUMENTS

AD1- ESA-QCA-RTP-LM139-00102
AD-2 ESA/SCC Detailed Specification No. 9103/004 “Integrated Circuits, Silicon Monolithic, Quad Bipolar Voltage Comparator, Based on Types LM139 and LM139A”

3 TEST DESCRIPTION

Five (5) LM139, Flight Lot, National Semiconductors devices were selected for TID irradiation testing at the ESTEC ^{60}Co facility. To investigate Enhanced Low Dose Rate Effects, irradiation tests employing two different dose rates (high and low dose rates) were planned. The high dose rate tests were performed at 48 rad/min while the low dose rate tests were performed at 0.8 rad/min which is at the lower capability limits of the ESTEC ^{60}Co facility.

Of the devices received, one was employed as a reference device while four were serialised for irradiation tests. A special test board (figure 1) was manufactured to accommodate two devices during irradiation exposure. Each device on the test board was biased independently with operating conditions as provided by the SMART1 project. The device operating / temperature conditions and applied dose rates are listed in table1.

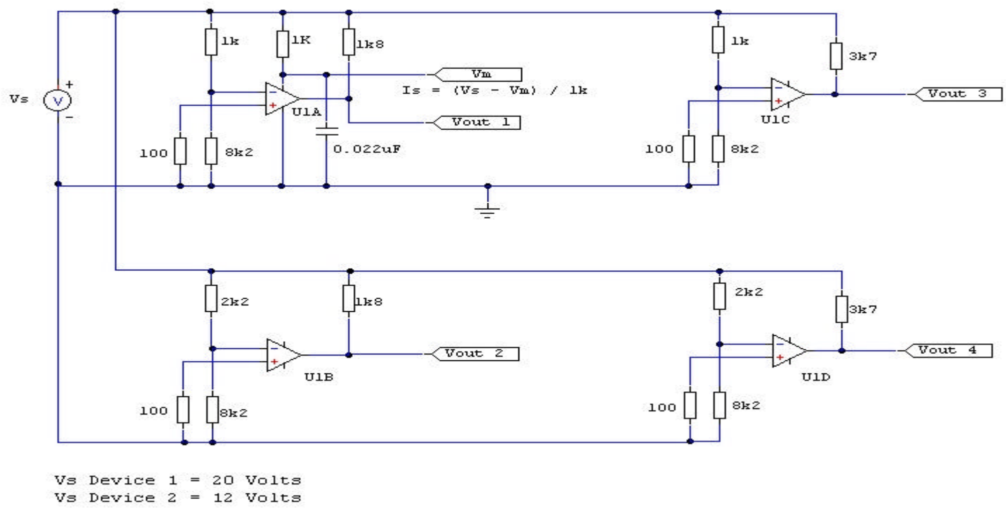

Figure 1 Schematic diagram of LM139 irradiation test circuit.

Parameter	Ref. Dev.	Dev1	Dev2	Dev3	Dev4
Bias During Irradiation	NA	+20V	+12V	+20V	+12V
Dose Rate	NA	48rad/min	48rad/min	0.8rad/min	0.8rad/min
Irradiation Temperature	$20 \pm 3\ ^{o}C$	$20 \pm 3\ ^{o}C$	$20 \pm 3\ ^{o}C$	$20 \pm 3\ ^{o}C$	$20 \pm 3\ ^{o}C$	$20 \pm 3\ ^{o}C$

Table 1 Irradiation Test Conditions

3.1 Measurement set-up

Two sets of measurements were performed according to AD1 (listed in tables 2 and 3). Continuous measurements, during irradiation, were performed employing an HP-VEE system consisting of:

- HP 6626A System DC Power Supply
- HP 34970A Data Acquisition / Switch Unit

Parametric measurements were performed employing a SZ parametric tests system:

- SZ M3000 Test Station Sm02B
- M3000 TA09B Test Adapter
- Software UTS-Version 2.3.3

Measurement number	Devices 1,2,3 and 4
1	Output Voltage Comparator A
2	Output Voltage Comparator B
3	Output Voltage Comparator C
4	Output Voltage Comparator D
5	Device power consumption

Table 2 Continuous measurements for each device during irradiation.

Test Parameter
Vos
+Is
Ib
Ib+
Ib-
Ios
Avo
CMRR
PSRR+

Table 3 Parameters measured by the SZ parametric Test System

The high dose rate tests were performed first to quickly obtain information on the behavior of the components under irradiation. The time between irradiation stop, performing parametric measurements and starting irradiation was always less than 30min. 6 irradiation steps were performed and parametric measurements performed after each step (parametric also for the reference device except after the first irradiation run). Pre-irradiation measurements were performed on all devices. Table 4 illustrates the high dose rate irradiation and measurement history. Due to an erroneous setting of a SZ software parameter, most post 5 and 7 krad parametric measurements were not recorded.

Irradiation steps	Ref. Dev.	Dev1	Dev2
Pre-rad. Par. measurements	Yes	Yes	Yes
1 krad (H_2O)	NA	Yes	Yes
par. measurements	NA	Yes	Yes
3.3 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes
5 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes
7krad (H_2O)	NA	Yes	Yes
Par. measurements	Yes	Yes	Yes
10 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes
15 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes

Table 4 High Dose Rate Irradiation Test procedure

The low dose rate tests were performed after completion of the high dose rate irradiation tests. The time between irradiation stop, performing parametric measurements and starting irradiation was always less than 30min. 8 irradiation steps were performed including parametric measurements after each step (parametric measurements also on the reference device). Pre-irradiation measurements were also performed on samples being irradiated. Table 5 illustrates the low dose rate irradiation and measurement history. The continuous measurement system often failed during these measurements thus, only a few data points are available. The low dose rate measurements were terminated at approximately 12krad as irradiation tests for new LM139a devices were urgently requested by the SMART1 project.

Irradiation steps	Ref. Dev.	Dev3	Dev4
Pre-rad. Par. measurements	Yes	Yes	Yes
1 krad (H_2O)	NA	Yes	Yes

par. measurements	YES	Yes	Yes
2.6 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes
3.3 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes
4.9 krad (H_2O)	NA	Yes	Yes
Par. measurements	Yes	Yes	Yes
5.9 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes
7 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes
9.4 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes
11.7 krad (H_2O)	NA	Yes	Yes
par. measurements	Yes	Yes	Yes

Table 5 Low Dose Rate Irradiation Test procedure

3.2 Thermal conditions

All irradiations and measurements were performed at room temperature (20 ± 3 ^oC).

3.3 Dosimetry

A calibrated NE2571, 0.60cc air ionisation chamber read by a calibrated Farmer 2670 dosimeter was used to measure the Total Ionising Dose.

3.4 Test Results (high dose rate)

Figures 2 to 10 illustrate the parametric results for the reference device and devices1 and 2. Results from all four outputs of each device has been included. The limit (AD2) for which a parameter is considered out of spec has also been added to each graph.

Figures 11 to 13 illustrate results acquired as the devices were being irradiated. These include output voltage measurements and power consumption measurements.

Following figure13, a discussion of the results is presented.

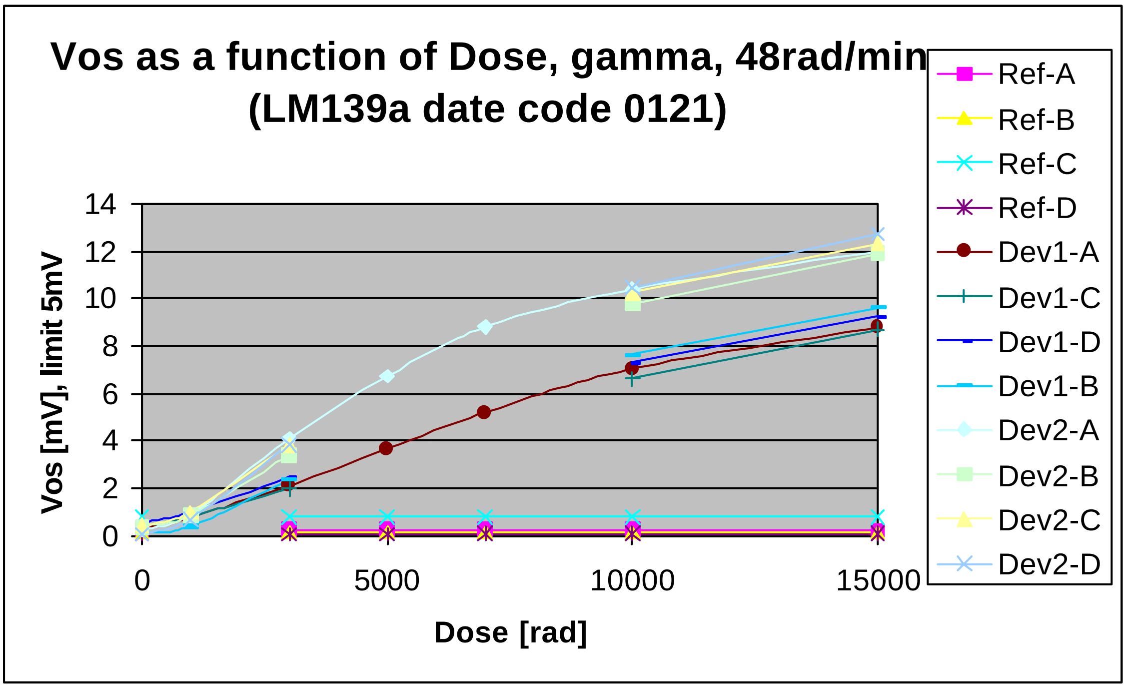

Figure 2 Vos as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

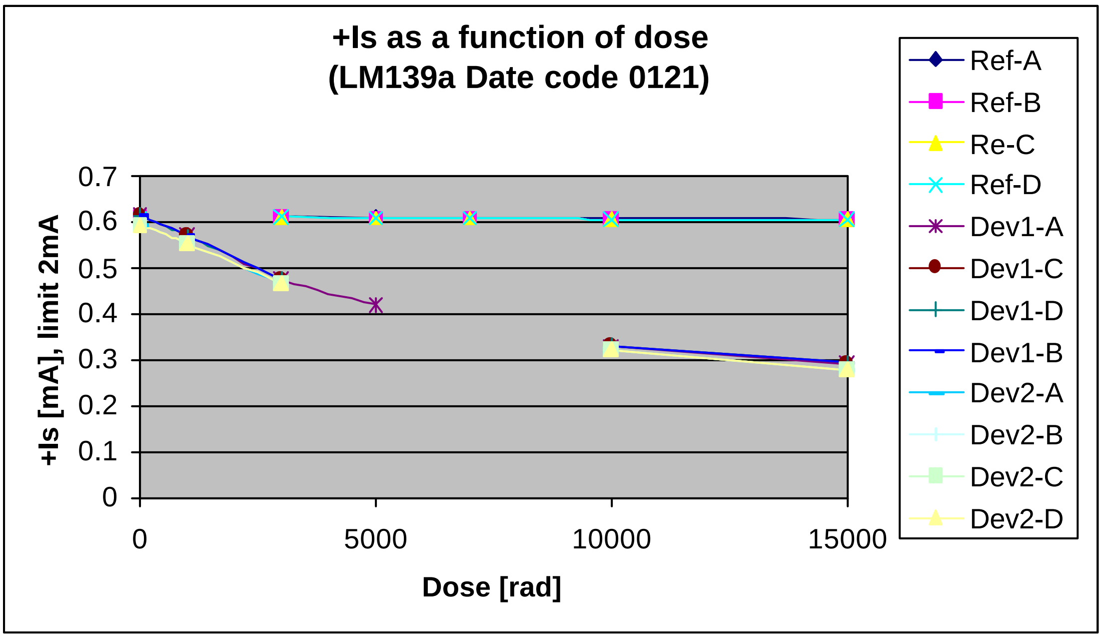

Figure 3 +Is as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

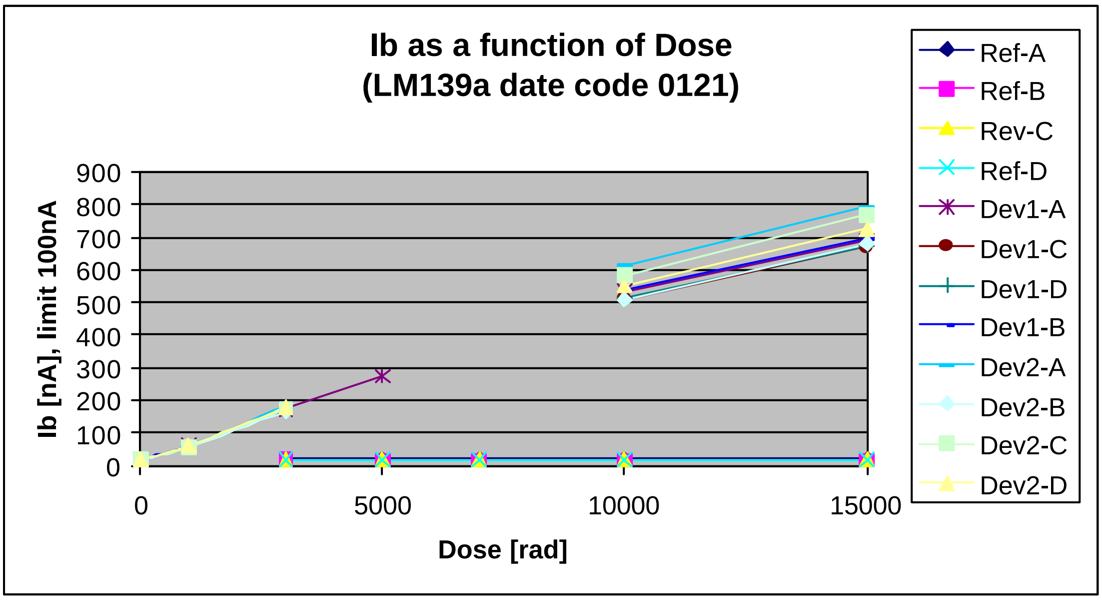

Figure 4 Ib as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

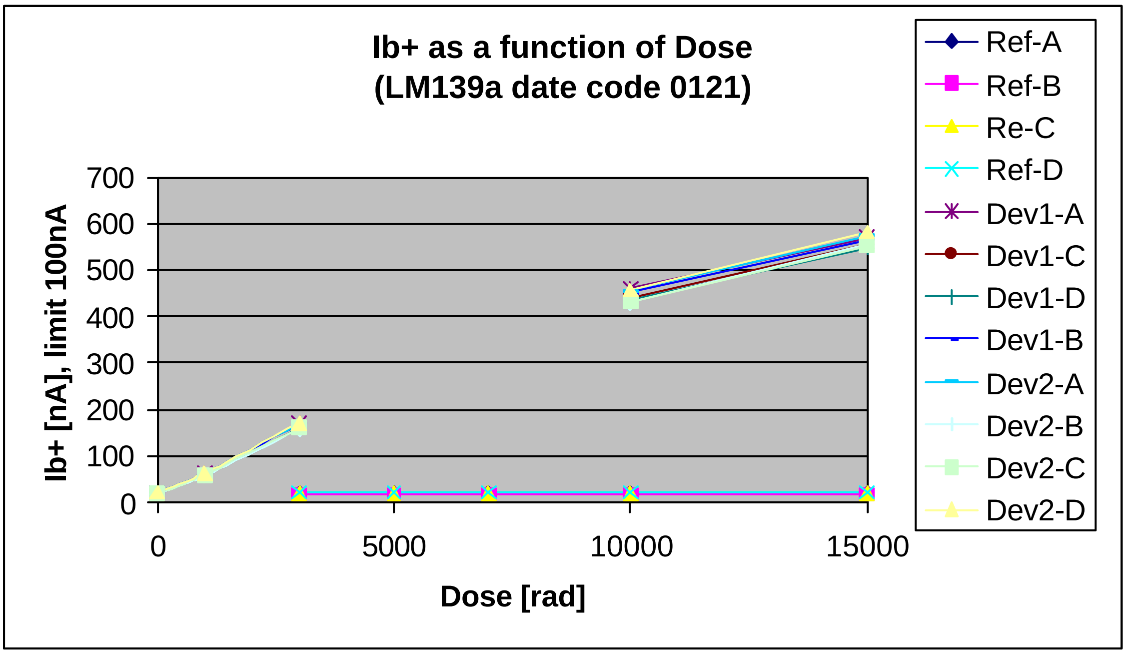

Figure 5 Ib+ as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

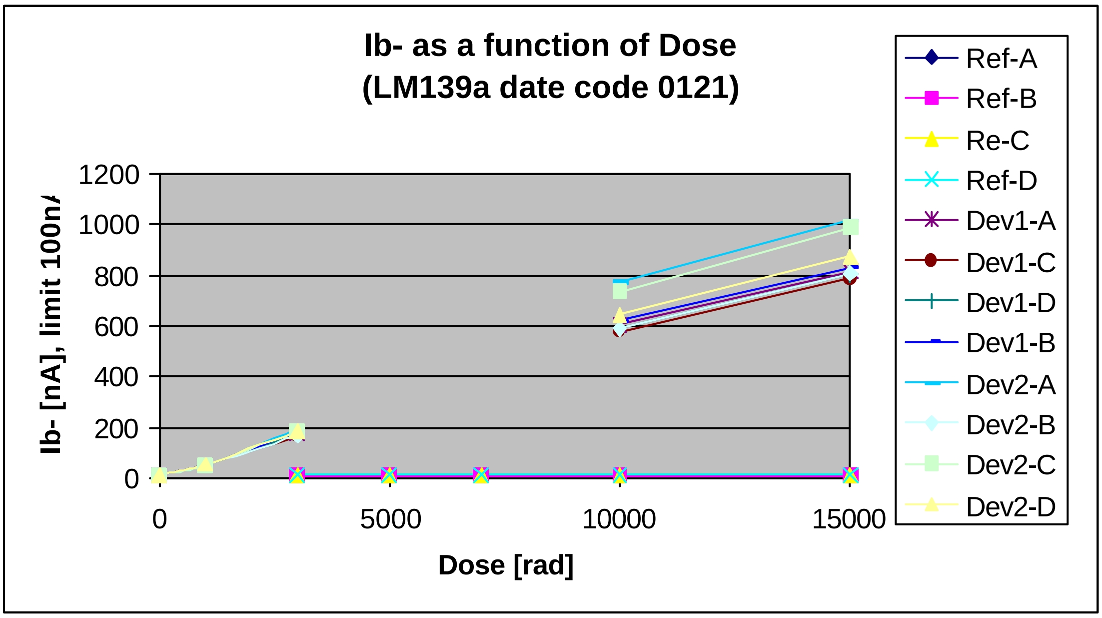

Figure 6 Ib- as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

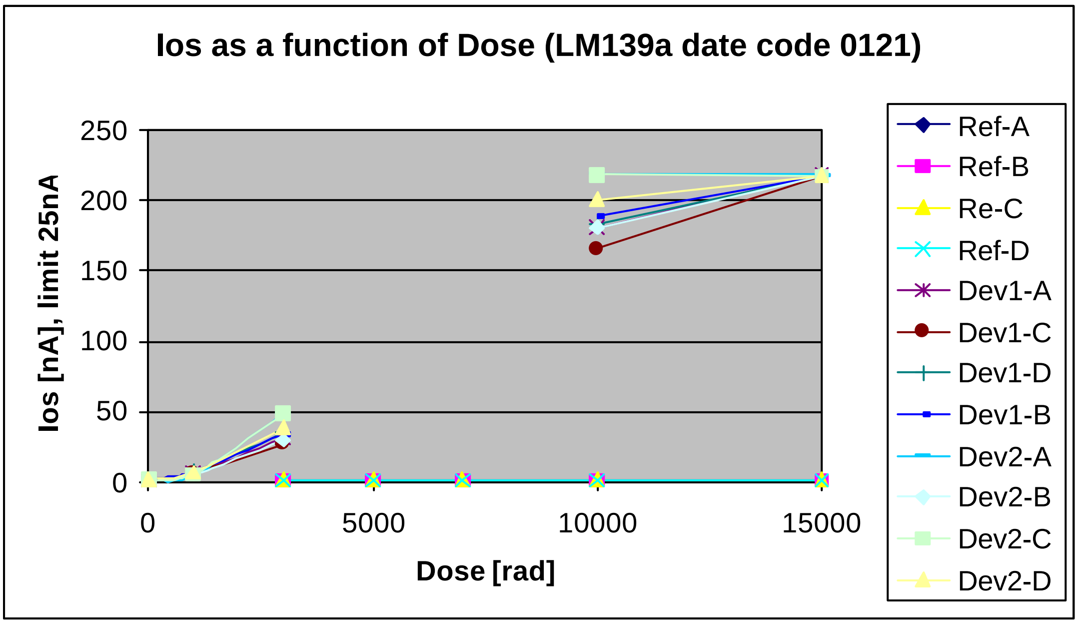

Figure 7 Ios as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

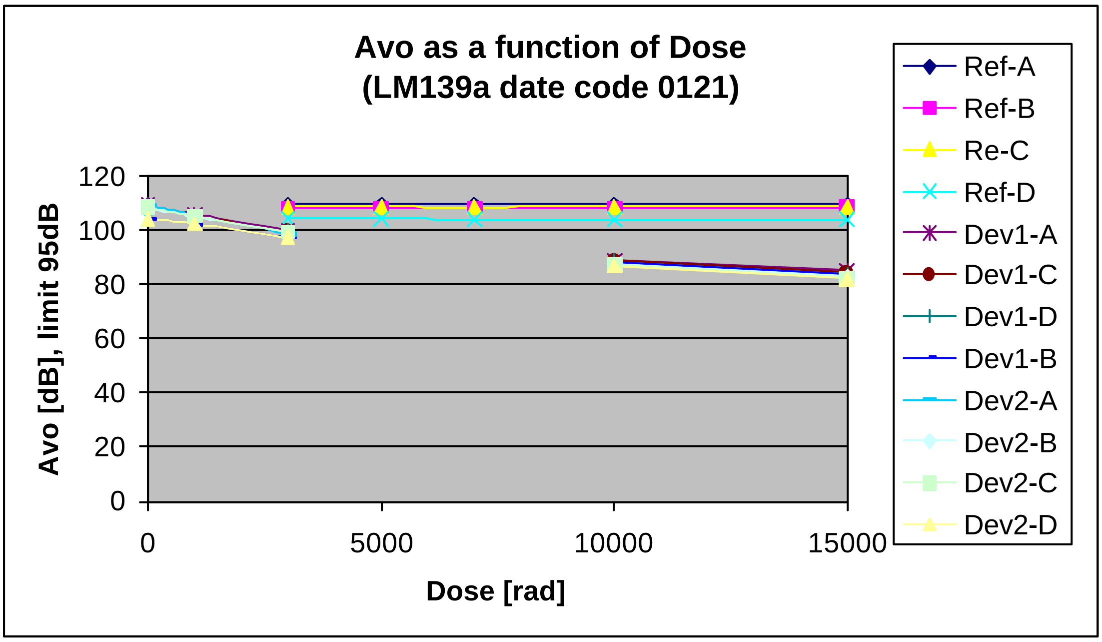

Figure 8 Avo as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

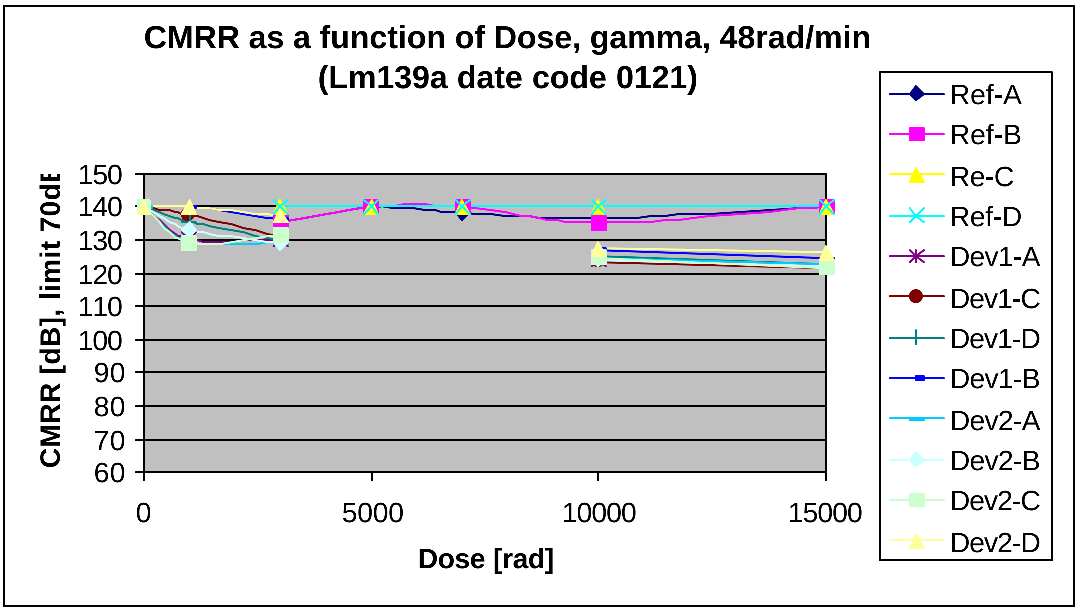

Figure 9 CMRR as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

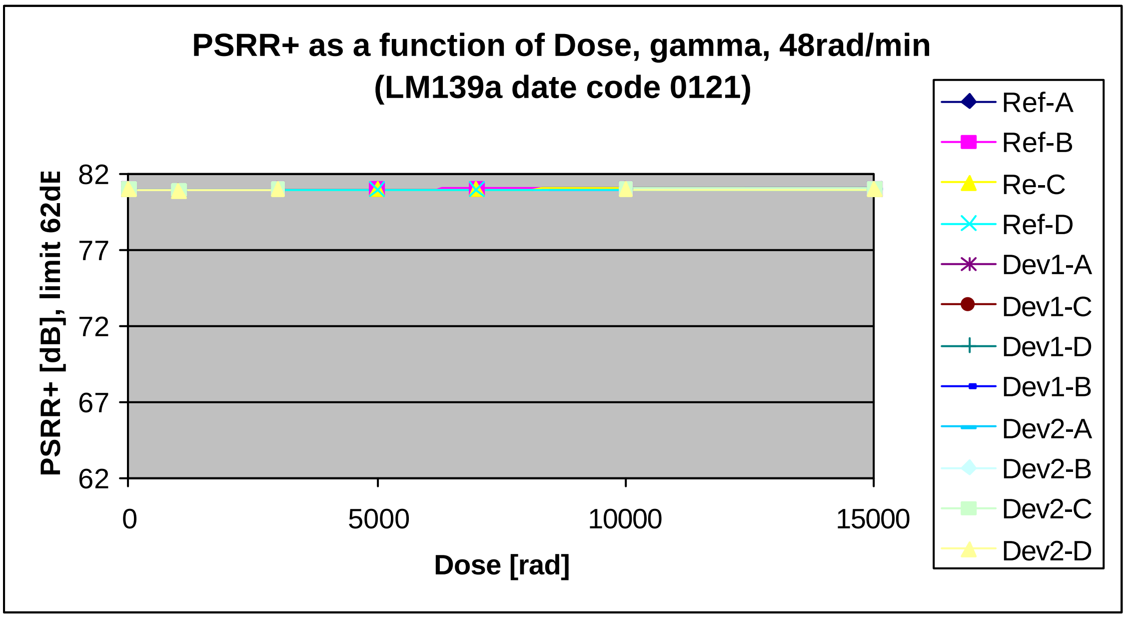

Figure 10 PSRR+ as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

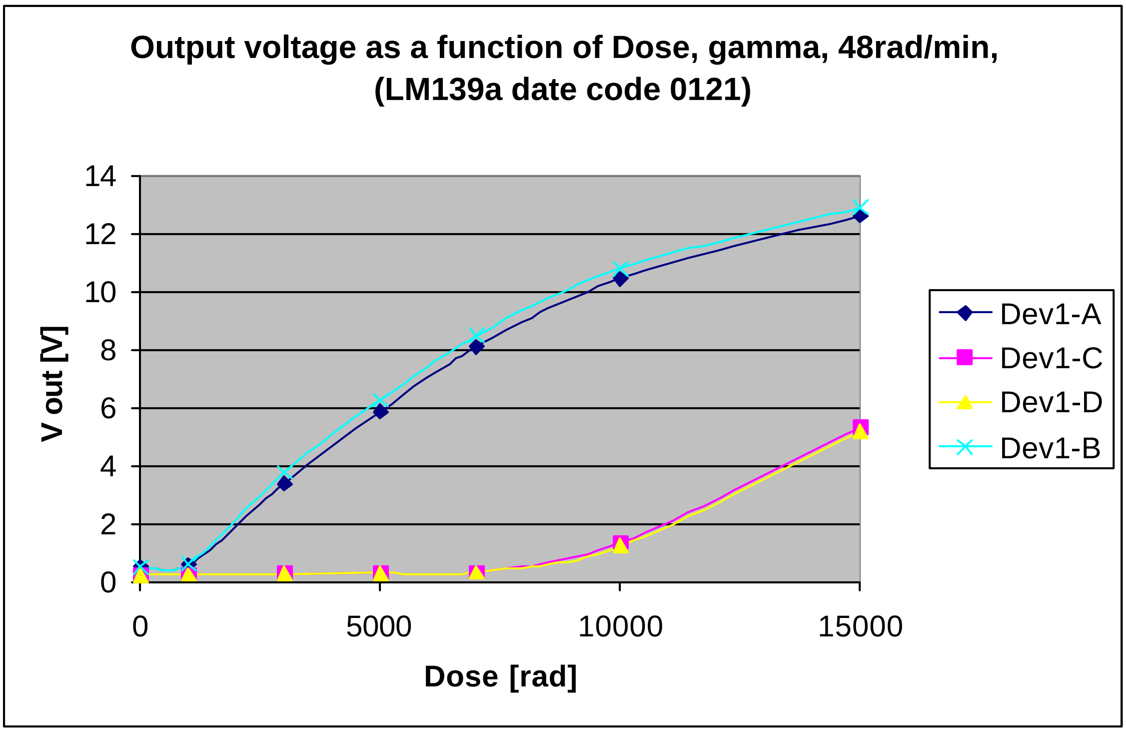

Figure 11 Real time measurement of output voltage during irradiation, device1 biased to 20V.

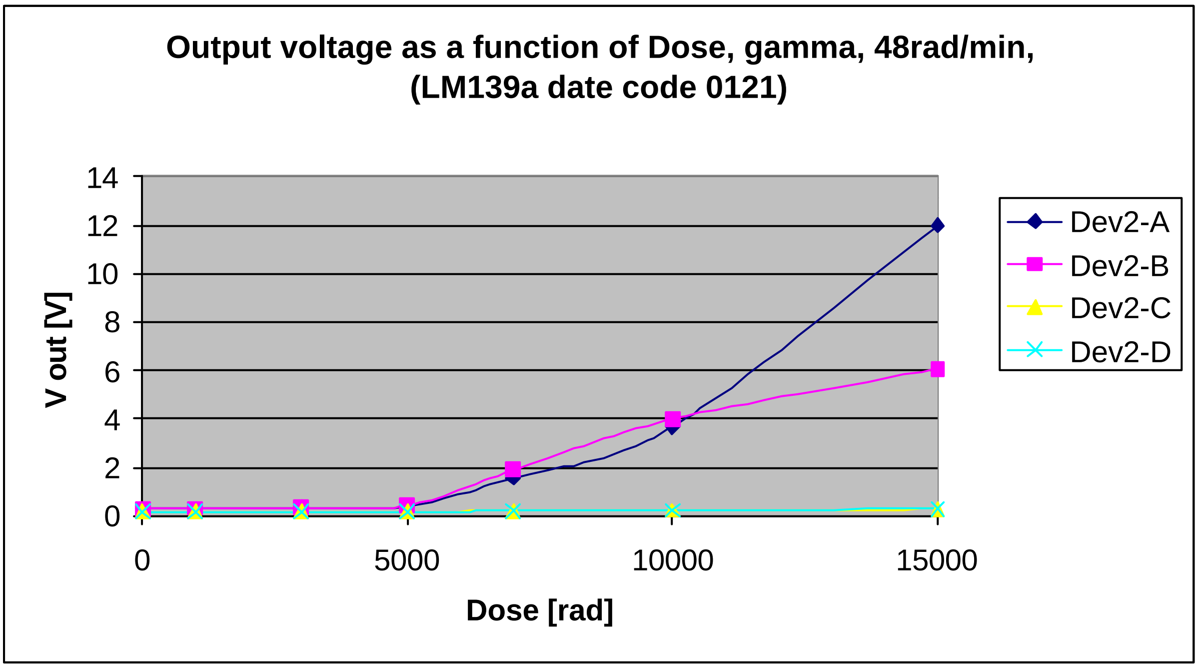

Figure 12 Real time measurement of output voltage during irradiation, device2 biased to 12V.

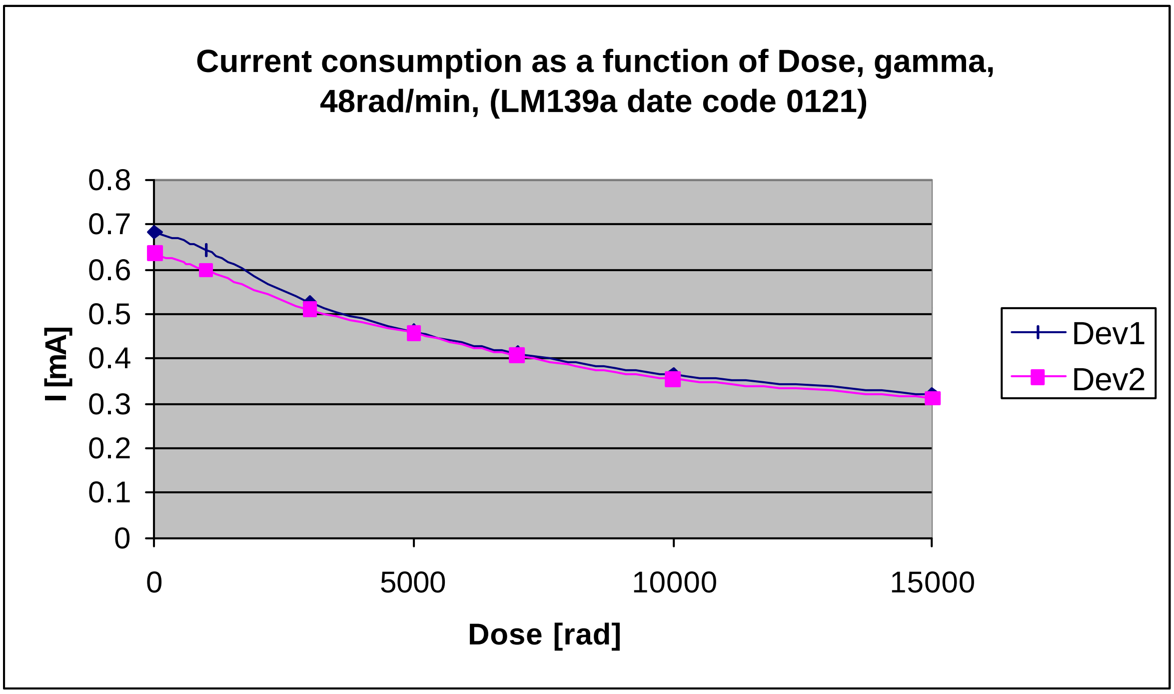

Figure 13 Real time measurement of current consumption during irradiation, device1 biase to 20V and device2 biased to 12V.

Already after 1krad, the continuous measurements of device1 indicated a degradation of the output voltage parameter. This degradation was detected for outputs A and B indicating these open-collector outputs are turning off. A degradation of outputs C and D was only observed at an accumulated dose of 7krad. Outputs A and B, of device2, did not exhibit a degradation before the 5krad level.

The results in figures 11 and 12 illustrate that the open-collector outputs with increasing total accumulated dose are gradually turned off. In fact, at 15krad, output A of device 2 is fully turned off with a measured voltage of 12V (rail voltage). These results indicate that the degradation of the outputs is larger for outputs sinking most current (Dev-1 outputs A and B 11mA, Dev-1 outputs C and D 5.3mA, Dev-2 outputs A and B 6.5mA, Dev-2 outputs C and D 3.2mA).

Figure 13 illustrate a good correlation between device1 and 2 power consumption values. The power consumption of both devices decreases with increasing total accumulate dose.

The parametric measurements illustrate that Ib, Ib+ and Ib- of both devices were out of specification already after 1.5 to 2krad, figures 4, 5 and 6. At 15krad these values were 5 to 6 times the specified upper limit of 100nA.

Ios for both devices was out of specification at approximately 3krad, figure 7. At 15krad this value was approximately 8 times the specified upper limit of 25nA.

Vos for device2 was out of specification between 3 and 5 krad, for device1 this number was closer to 7krad, figure 2.

Avo for both devices was out of specification at approximately 10krad, figure 8.

+Is, CMRR and PSRR+ were within their specified limits up to 15krad.

3.4.1 CONCLUSION HIGH DOSE RATE TEST

Both parametric and functional measurements illustrate that the devices exhibit performance degradation already after 1 to 2krad total accumulated dose. This trend is increasing for increasing total dose values.

3.5 Test Results Low Dose Rate

Figures 14 to 22 illustrate the parametric measurement results for the reference device, devices1 and 2. Results from all four outputs of each device has been included. The limit (AD2) for which a parameter is considered out of spec has also been added to each graph.

Figures 23 to 25 illustrate results acquired as the devices were being irradiated. These include output voltage measurements and power consumption measurements.

Following figure25, a discussion of the results is presented.

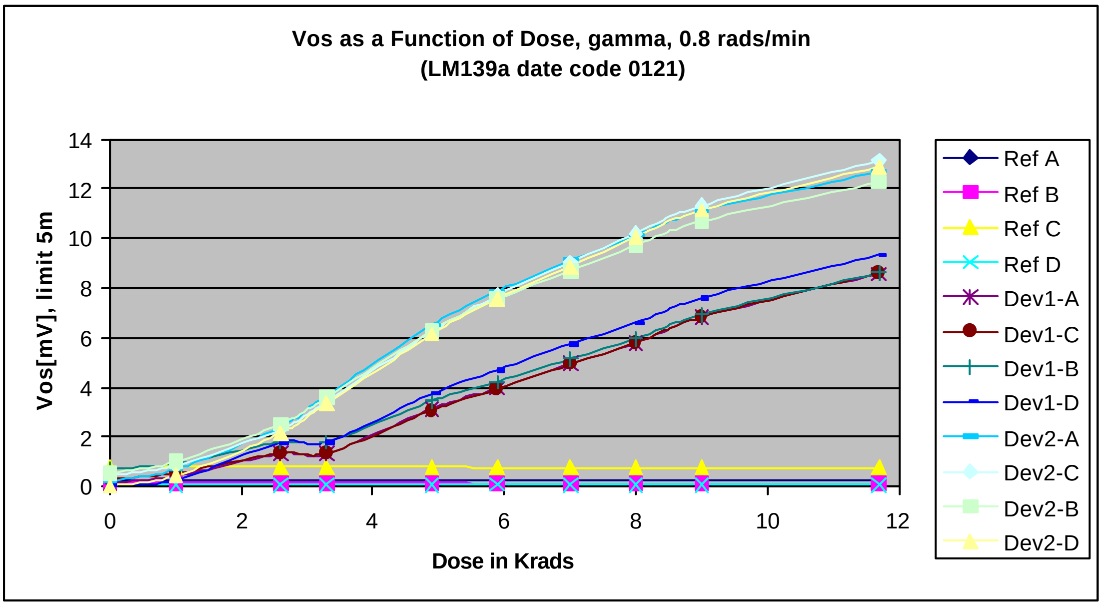

Figure 14 Vos as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

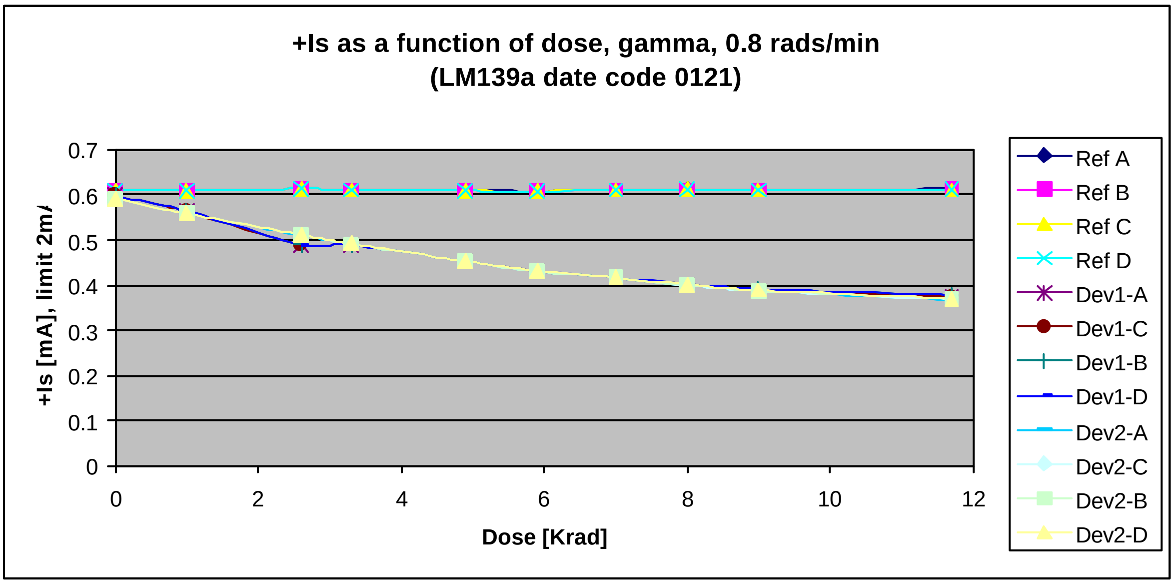

Figure 15 +Is as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

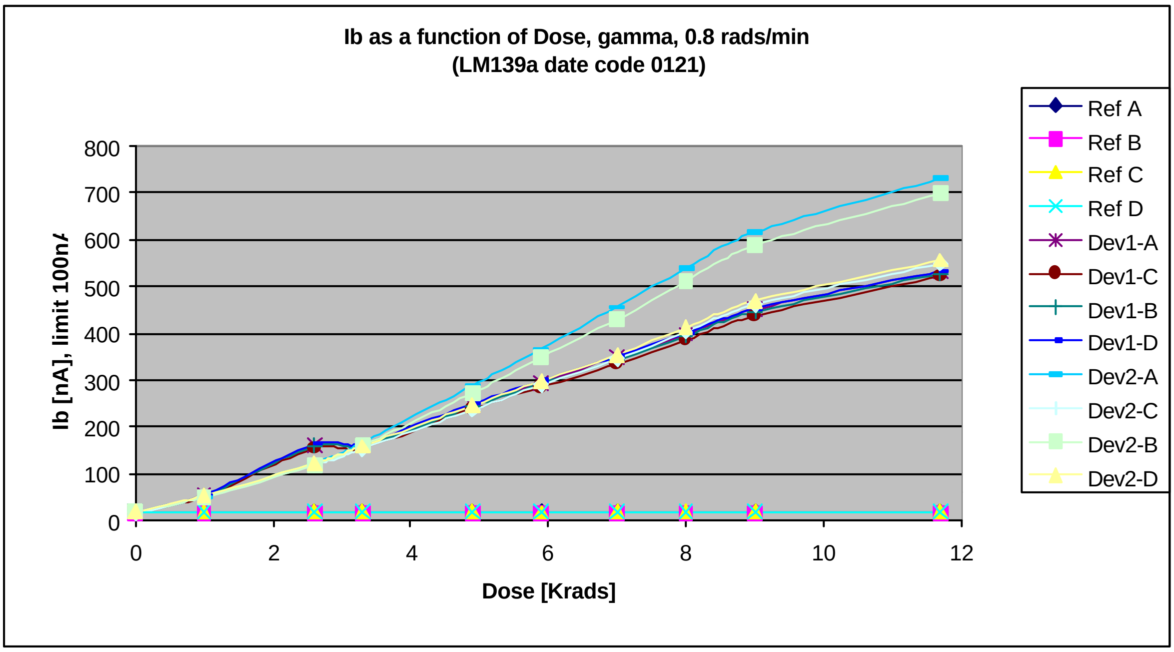

Figure 16 Ib as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

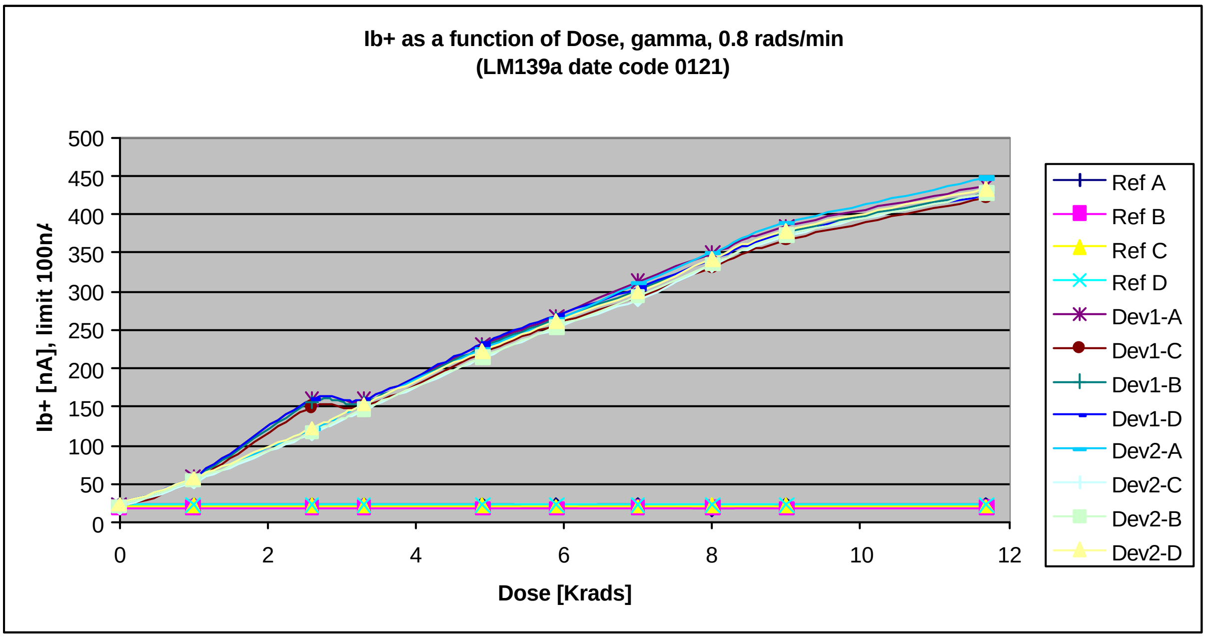

Figure 17 Ib+ as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

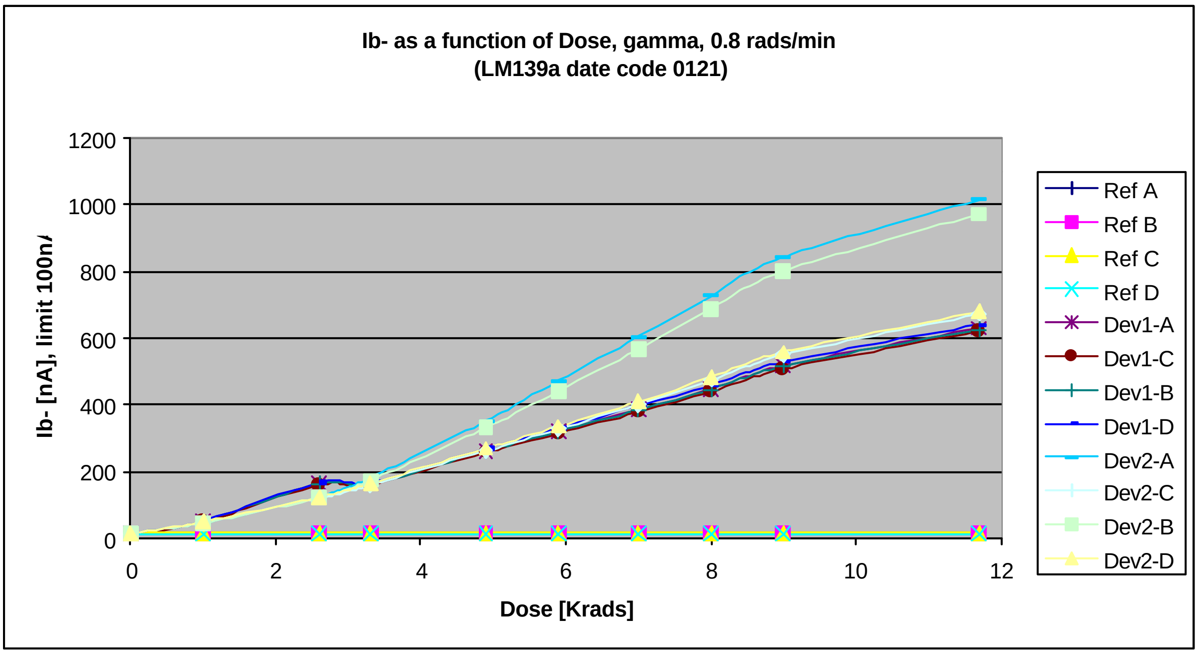

Figure 18 Ib- as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

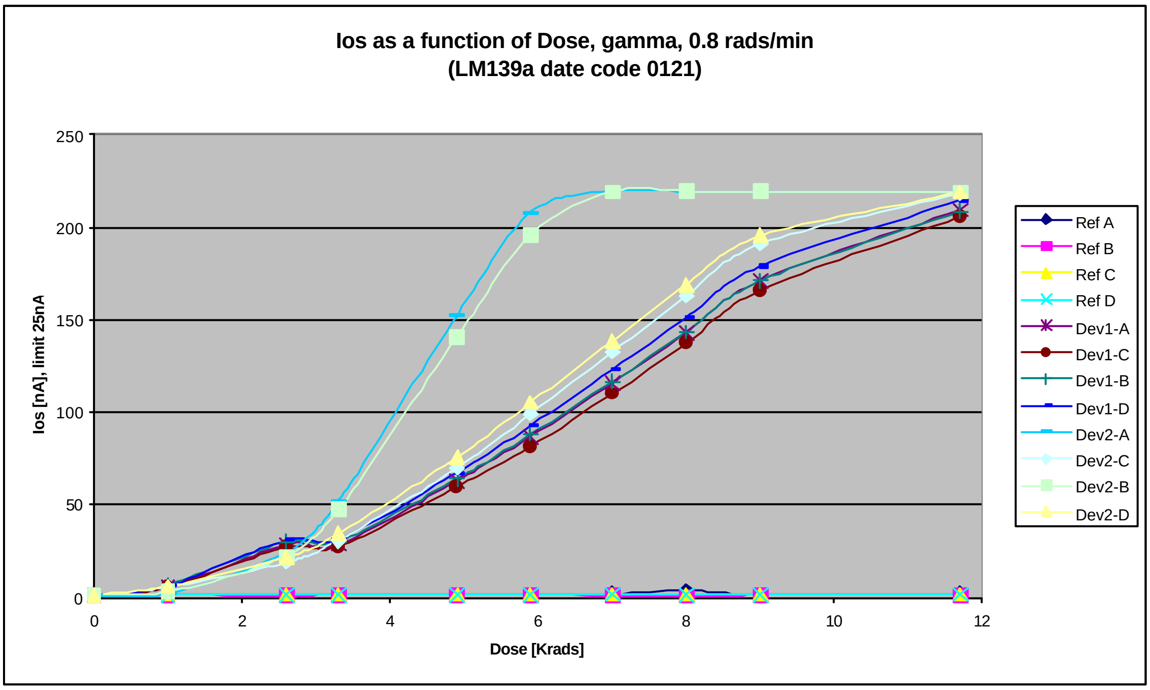

Figure 19 Ios as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

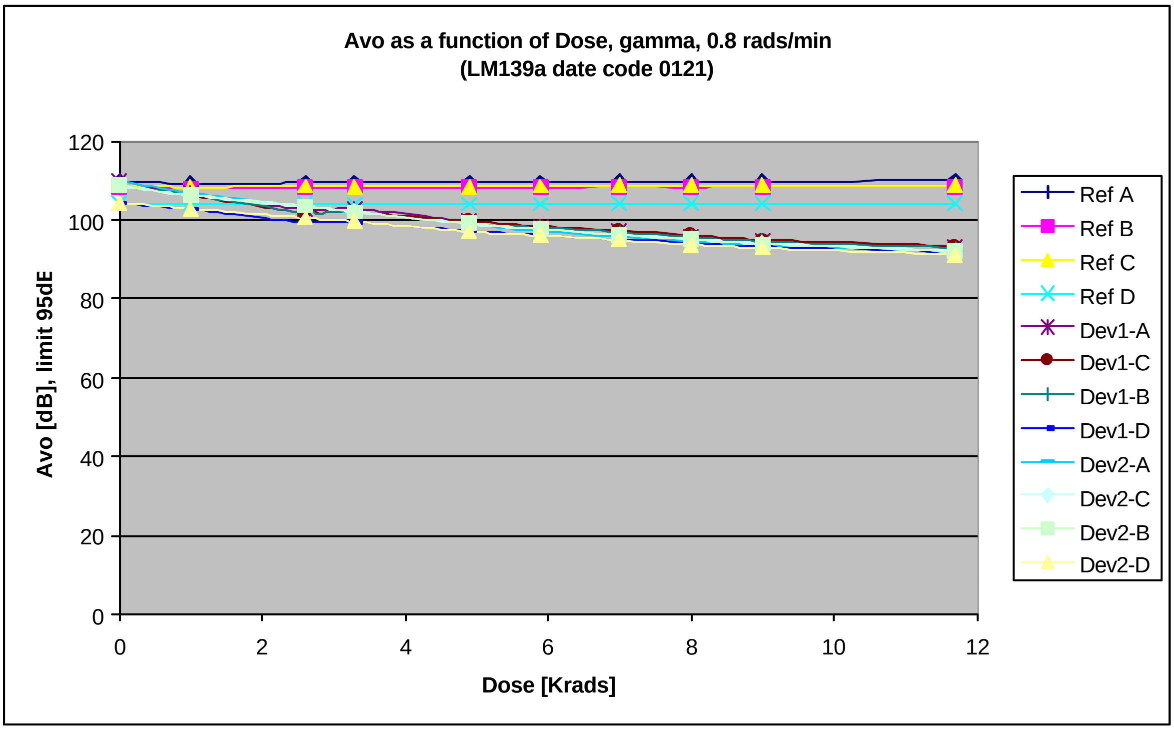

Figure 20 Avo as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

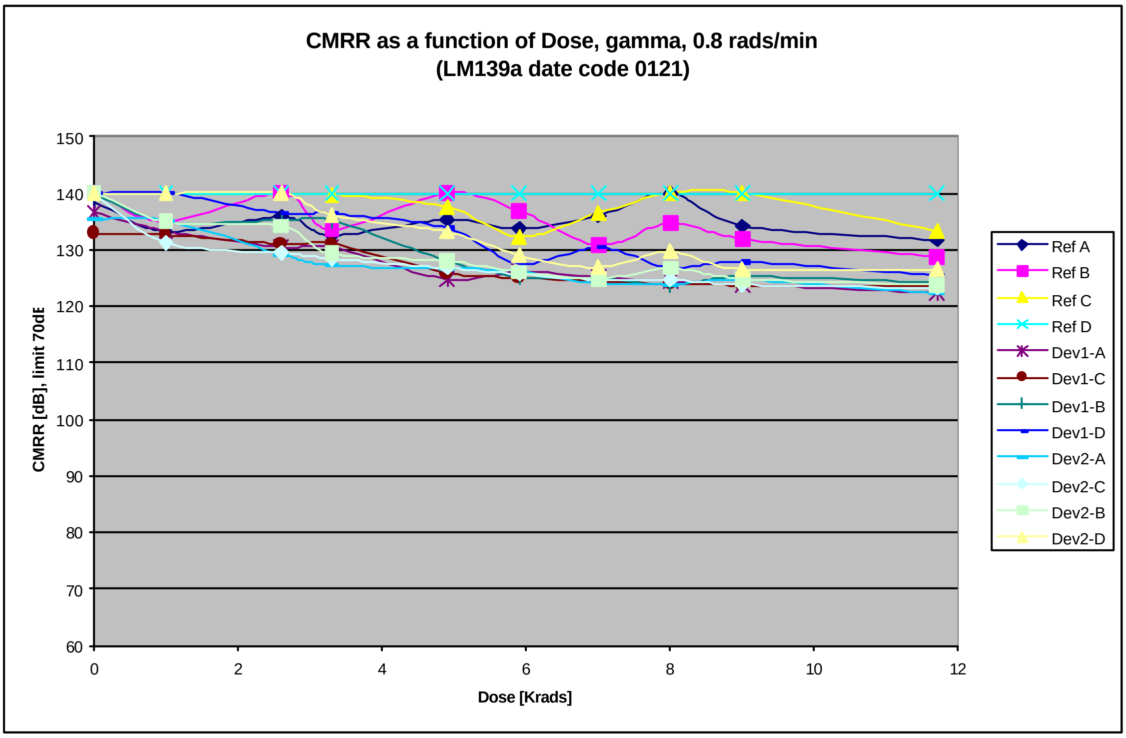

Figure 21 CMRR as a function of dose. During irradiati on device1 was biased at 20V and device2 at 12V.

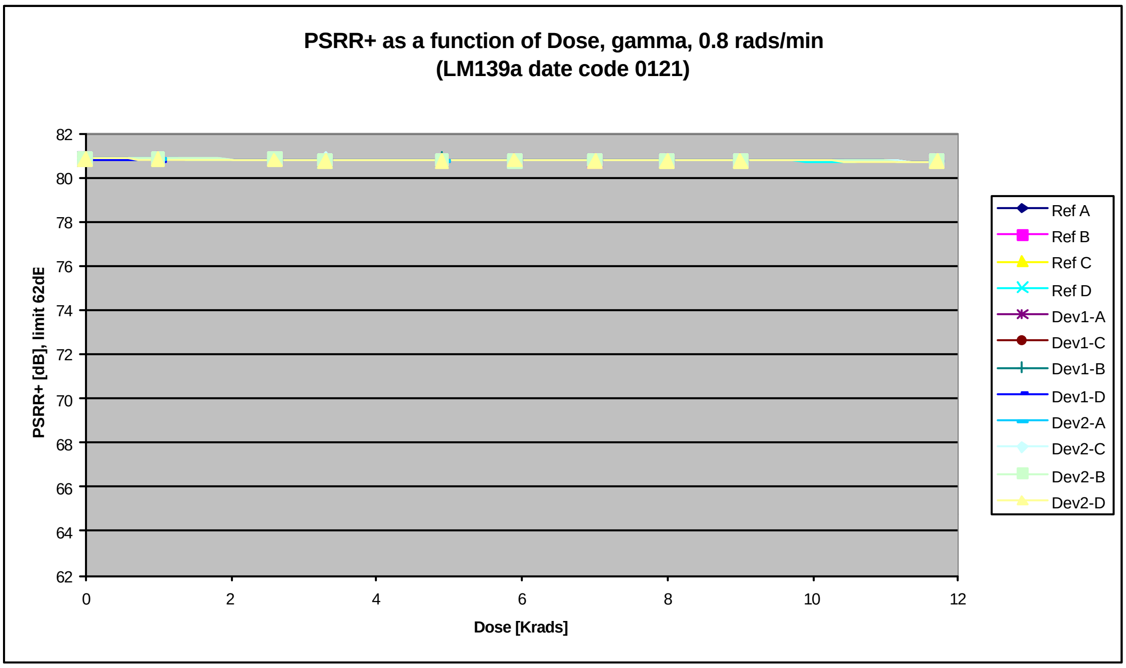

Figure 22 PSRR+ as a function of dose. During irradiation device1 was biased at 20V and device2 at 12V.

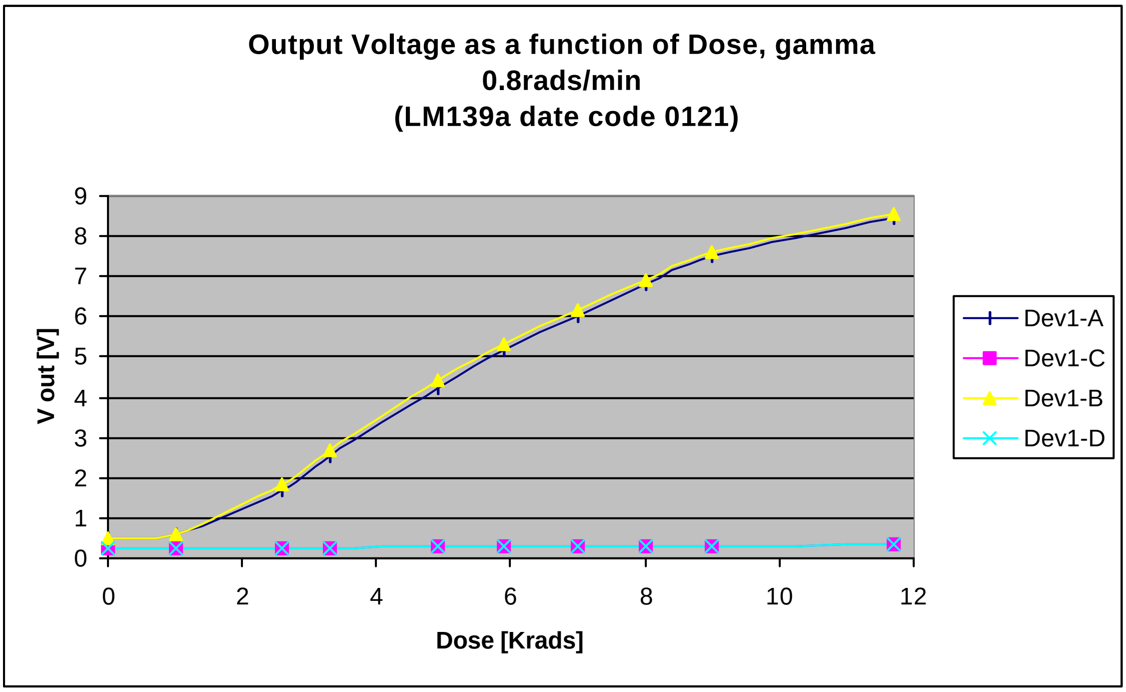

Figure 23 Real time measurement of output voltage during irradiation, device1 biased to 20V.

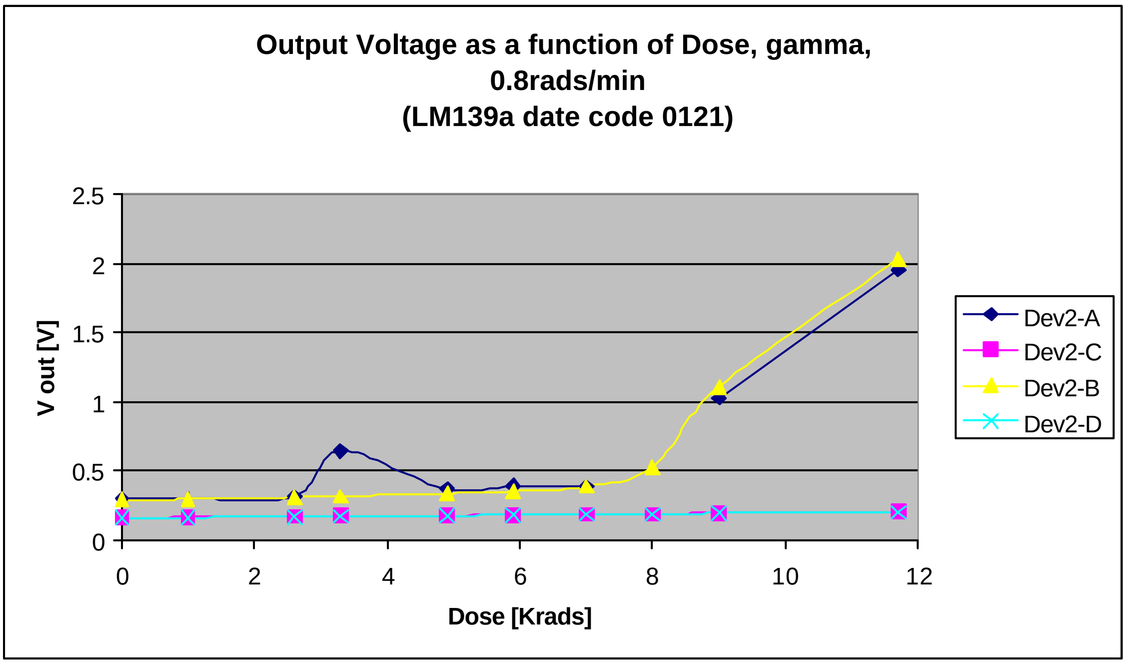

Figure 24 Real time measurement of output voltage during irradiation, device2 biased to 12V.

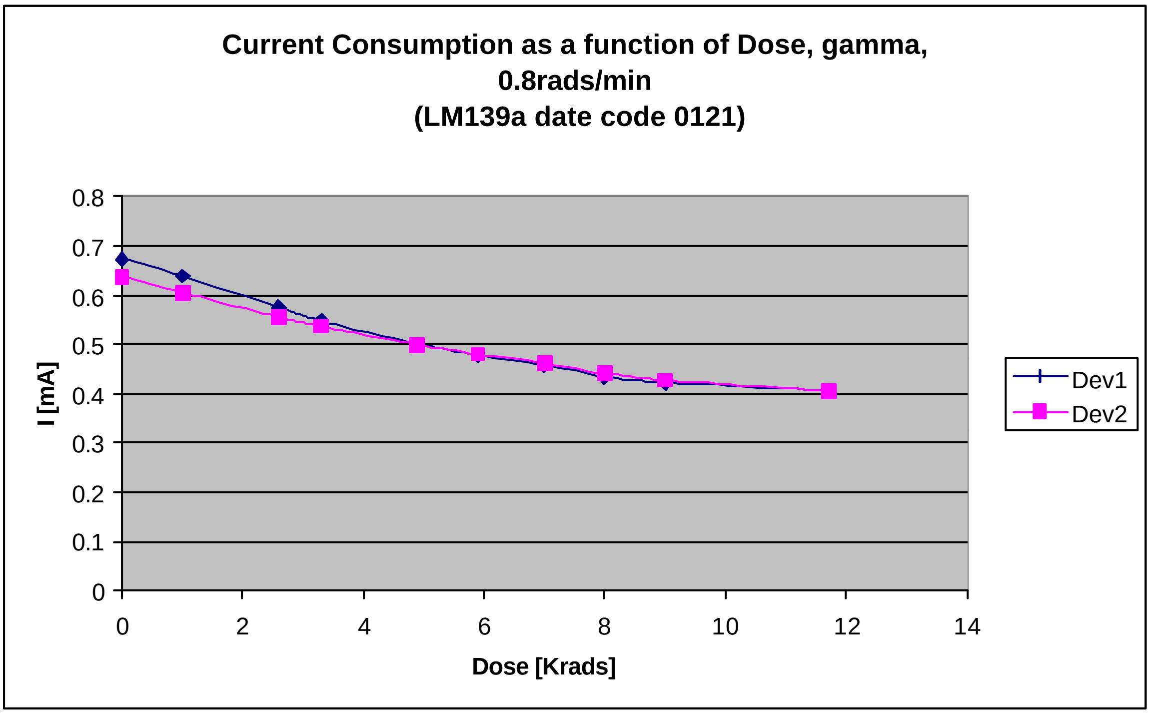

Figure 25 Real time measurement of current consumption during irradiation, device1 biase to 20V and device2 biased to 12V.

Already after 1krad, the continuous measurements of device1 indicated a degradation of the output voltage level. This degradation was detected for outputs A and B indicating their open-collector outputs turning off. No degradation was observed for outputs C and D. Outputs A and B, of device2, only exhibit degradation after the 8krad level. No degradation was observed for outputs C and D of device 2.

The results in figures 23 and 24 illustrate that the open-collector outputs with increasing total accumulated dose are gradually turned off. These results indicate that the degradation of the outputs is larger for outputs sinking most current (Dev-1 outputs A and B 11mA, Dev-1 outputs C and D 5.3mA, Dev-2 outputs A and B 6.5mA, Dev-2 outputs C and D 3.2mA).

Figure 25 illustrate a good correlation between device1 and 2 power consumption values. The power consumption of both devices decreases with increasing total accumulate dose.

The parametric measurements illustrate that Ib, Ib+ and Ib- of both devices were out of specification already after approximately 2krad (figures 16, 17 and 18). At 12 krad these values were approximately 5 to 10 times the specified upper limit of 100nA.

Ios for both devices was out of specification at approximately 2krad, figure 19. At 12krad this value was approximately 8 times the specified upper limit of 25nA.

Vos for device2 was out of specification at approximately 4krad, for device1 this number was closer to 6krad, figure 14.

Avo for both devices was out of specification at approximately 8krad, figure 20.

+Is, CMRR, and PSRR+ were within their specified limits up to 12krad.

3.5.1 CONCLUSION LOW DOSE RATE TEST

Both parametric and functional measurements illustrate that the devices exhibit performance degradation already after 1 to 2krad total accumulated dose. This trend is increasing for increasing total dose values.

3.6 Conclusion Total Dose Testing

Both high and low dose rate tests illustrate that the devices tested already show parameter degradation after exposure to approximately 1 to 2 krad of gamma irradiation. This is true both for parametric as well as functional measurements.

No conclusive evidence was observed indicating enhanced low dose rate effects (for the dose rates employed here). Some of the parameters do degrade slightly earlier at low dose rate tests compared to high dose rate tests. However, the opposite is observed for functional measurements (output voltage measurements).

The devices investigated during this test campaign are considered sensitive to ionizing radiation.