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RADIATION TEST REPORT FOR ENHANCED LOW DOSE RATE SENSITIVITY (ELDRS) TESTING

QUAD 2N2222A TRANSISTORS (JANS2N6989U)

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CHANGE RECORD

Issue: 1 Revision: 1

reason for change/*raison du changement*	page(s)/*page(s)*	paragraph(s)/*paragraph(s)*

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Test Report Number	
Project	
SCC Component no.	
Component Designation	Quad npn transistor JANS2N6989U
Irradiation Spec. no.	
Family	Integrated Circuits
Group	Silicon Monolithic
Package	LCC-20
Component Specification	Mil-Prf-19500/559
Test House Name	ESA / ESTEC
Irradiation Test Plan Number	
Manufacturer name	Microsemi
Application type of Acceptance	
Serial Number of samples	Six (6) samples serialised as Ref, A, B, C, D and E
Manufacturing Date Code	
Irradiation Measurement Interval: Biased Unbiased: Circuit Reference: Supply Voltage: Temp ^{o}C: Duration:	Low Dose rate (LDR) up to 19.8 krad(Si), High dose rate (HDR) (device C) up to 103krad(Si), High Dose Rate (devices D and E) 156krad(Si) Yes (2 parts LDR and 3 parts HDR) 1V Room temperature 20 ± 3
Electrical Measurement Parameters	
Facility Source: Energy: Dose Rate: Absorbed Material: Thickness: Temperature ^{o}C:	 60Co 0.5 rad(Si)/min (LDR) and 60 rad(Si)/min (HDR) N/A N/A 20 ± 3
Dosimetry / Calibration method.	A calibrated NE2571, 0.6cc air ionisation chamber read by a calibrated Farmer 2670 dosimeter.
Anneal Test Biased Unbiased Bias Circuit Reference Supply Voltage Duration	 No Yes 1, 2 and 4 weeks at room temperature followed by 6 days at 100°C for the LDR case. Device C (HDR), 3 week room temperature anneal .

1 INTRODUCTION

The following document contains the TID Radiation Test Report for the 2N6989 quad transistors device. The tests were performed to identify possible ELDRS effect of these devices.

2 APPLICABLE DOCUMENTS

AD1- ESA/SCC 22900 “Total Dose Steady-State Irradiation Test Method”

3 TEST DESCRIPTION

Six (6) JANS2N6989U, Microsemi devices (date code 0347) were selected for TID irradiation testing at the ESTEC ^{60}Co facility. Irradiations were performed at a dose rate of 0.5 rad(Si)/min and 60 rad(Si)/min. Post irradiation annealing measurements were also performed on some of the devices.

Of the selected devices, one was assigned as a reference device while, five were serialised for radiation exposure: two devices were irradiated at low dose rate and three at high dose rate. After each exposure-step the components were removed and tested on the SZ-test system for parametric measurements. Each irradiation test-board accommodated and biased two quad transistors. The biasing scheme of the quad transistor is illustrated in Figure 1. The operating conditions during irradiation were provided by the project. The device operating conditions, temperature conditions and applied dose rates are listed in Table 1.

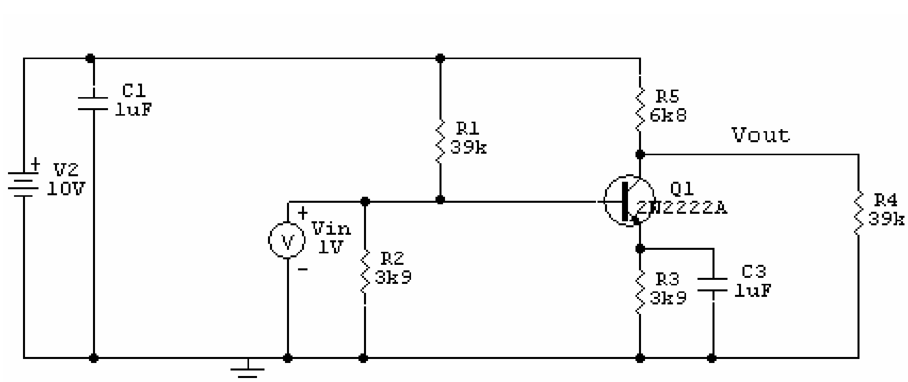

Figure 1: quad transistor biasing conditions for irradiation

Parameter	Ref. Dev.	Dev A	Dev B	Dev C	Dev D	Dev E
Bias During Irradiation	NA	+1V	+1V	+1V	+1V	+1V
Dose Rate	NA	0.5rad(Si)/min	0.5rad(Si)/min	60rad(Si)/min	60rad(Si)/min	60rad(Si)/min
Irradiation Temperature	20 ± 3 ^oC	20 ± 3 ^oC	20 ± 3 ^oC	20 ± 3 ^oC	20 ± 3 ^oC	20 ± 3 ^oC

Table 1 Irradiation Test Conditions

3.1 Measurement set-up

Two sets of measurements were performed one set of continuous measurements (in 10 min intervals) during the irradiation runs and one set of parametric measurement at regular intervals between irradiation steps. Continuous measurements were performed employing a 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 TA07T Test Adapter
- Software UTS-Version 2.5.1

Table 2 lists all parametric measurements performed and their limit values.

Table 2: Parameters measured by the SZ parametric Test System

Test Parameter	Limit	Conditions
VCE0	Lower 40V Upper 200V	IC=10mA
VEB0	Lower 6000V Upper 12000V	IB=0.01mA
ICB0	Upper 10nA	VCB=60V
IEB0	Upper 10nA	VBE=3V
VBEsat1	Lower 600mV Upper 1200mV	IB=15mA IC=150mA

VBEsat2	Lower 0 Upper 2000mV	IB=50mA IC=500mA
VCEsat1	Lower 0 Upper 300mV	IB=15mA IC=150mA
VCEsat2	Lower 0mV Upper 1000mV	IB=50mA IC=500mA
hfe (DC)	Lower 35 Upper 300	VCE=10V IC=0.1mA
hfe (DC)	Lower 50 Upper 300	VCE=10V IC=1mA
hfe (DC)	Lower 75 Upper 300	VCE=10V IC=10mA
hfe (DC)	Lower 100 Upper 300	VCE=10V IC=150mA
hfe (DC)	Lower 40 Upper 300	VCE=10V IC=500mA
hfe (DC)	Lower 50 Upper 300	VCE=1V IC=150mA
h21e(AC)	Lower 50 Upper 300	VCE=10V IC=1mA
h21e(AC)	Lower 75 Upper 375	VCE=1V IC=10mA

The time between irradiation stop, performing parametric measurements and starting irradiation for all irradiation steps were less than 30min. 17 irradiation steps were performed at low dose rate from devices A and B. Two irradiation steps were performed at high dose rate for device C and 7 steps at high dose rate for devices D and E. Parametric measurements were performed after each irradiation step (parametric also performed for the reference device). Pre-irradiation measurements were performed on all devices. Table 3, 4 and 5 list the irradiation and measurement history of all devices.

Table 3: Irradiation and measurement history – Low Dose Rate (LDR): 0.5 rad(Si)/min – Device A and B

Irradiation steps	Ref. Dev.	Dev A Biased	Dev B Biased
Pre-rad. Par. measurements	Yes	Yes	Yes
0.595 krad(Si)			
par. measurements	Yes	Yes	Yes

1.34 krad(Si)			
par. measurements	Yes	Yes	Yes
2.04 krad(Si)			
par. measurements	Yes	Yes	Yes
4.25 krad(Si)			
Par. Measurements	Yes	Yes	Yes
5.05 krad(Si)			
Par Measurements	Yes	Yes	Yes
6.95 krad(Si)			
par. measurements	Yes	Yes	Yes
6.72 krad(Si)			
par. measurements	Yes	Yes	Yes
10.33 krad(Si)			
par. measurements	Yes	Yes	Yes
11.02 krad(water)			
Par. Measurements	Yes	Yes	Yes
11.72 krad(Si)			
Par Measurements	Yes	Yes	Yes
12.43 krad(Si)			
par. measurements	Yes	Yes	Yes
14.52 krad(Si)			
par. measurements	Yes	Yes	Yes
15.24 krad(Si)			
par. measurements	Yes	Yes	Yes
15.94 krad(Si)			
Par. Measurements	Yes	Yes	Yes
16.76 krad(Si)			
Par Measurements	Yes	Yes	Yes
17.64 krad(Si)			
par. measurements	Yes	Yes	Yes
19.84 krad(Si)			
par. measurements	Yes	Yes	Yes

Table 4: Irradiation and measurement history - HDR: 60 rad(Si)/min – Device C

Irradiation steps	Dev C Biased
Pre-rad. Par. measurements	Yes
20.1 krad(Si)	
par. measurements	Yes
103.5 krad(Si)	
par. measurements	Yes

Table 5: Irradiation and measurement history - HDR: 60 rad(Si)/min – Device D, E

Irradiation steps	Dev D Biased	Dev E Biased
Pre-rad. Par. measurements	Yes	Yes
1.5 krad(Si)		
par. measurements	Yes	Yes
4.74 krad(Si)		
par. measurements	Yes	Yes
9.5 krad(Si)		
par. measurements	Yes	Yes
17.63 krad(Si)		
Par. Measurements	Yes	Yes
21.45 krad(Si)		
Par Measurements	Yes	Yes
85.83 krad(Si)		
par. measurements	Yes	Yes
156.15 krad(Si)		
par. measurements	Yes	Yes

3.2 Thermal conditions

All irradiations and measurements were performed at room temperature (20 ± 3 ^{o}C).

3.3 Dosimetry

A calibrated NE2571, 0.6cc air ionisation chamber read by a calibrated Farmer 2670 dosimeter was used to measure the Total Ionising Dose.

4 TEST RESULTS

Both low and high dose rate irradiation test were performed on the devices to obtain a direct verification of possible ELDRS effect. All irradiation test results for JANS2N6989U are presented in Figure 2 to Figure 19. The figures illustrate the parametric measurements regularly performed between each irradiation step. For improved visualization the results shown are the average of the four transistors in each device. Subsequently, the maximum and minimum deviation, from the mean value, is given in percentage in Table 6).Thus, Figure 2 to Figure 19 in combination with table 6 illustrate that none of the parameters for any individual transistor was out of specification. The figures also include the absolute maximum and/or minimum specified value for each parameter. Additionally, the annealing results following the low dose rate tests are indicated on the graphs. Figures 2 to 9 illustrate low dose rate results and indicate that parameters exhibit negligible drift. High dose rate results were not included in these figures as they also exhibited negligible changes. Thus, it was not possible from these parameters to determine whether the devices suffer from ELDRS. The hfe parameter exhibited the largest drift as illustrated in Figure 10 to Figure 15. These figures represent the data for both low and high dose rate tests up to a total ionizing dose of approximately 20krad(Si). Part A and B show similar degradation evolution however, the absolute value differ with the same ratio as found for the pre-radiation values. The high dose rate data exhibit similar behavior as that of the low dose rate data for the hfe(DC) parameter. However, there is a slight difference between the high and low dose rate behavior of the hfe(AC) parameter. Figure 18 and Figure 19 illustrate that the hfe(DC) and hfe(AC) parameters were within their specified limits up to a total ionizing dose level of 156krad(Si). No recovery of the hfe parameter was observed for low dose rate tested devices following 4-week room temperature anneal, however, some recovery was seen after 6 day high temperature anneal. Some recovery was observed for device C (high dose rate) following 3-week room temperature anneal.

Table 6: deviation from mean value in percentage

<table>
<tr><td></td><td colspan="2">hfe1, h21e</td><td colspan="2">VCEsat</td><td colspan="2">VBEsat</td><td colspan="2">VCE0</td><td colspan="2">VEB0</td></tr>
<tr><td></td><td>min</td><td>max</td><td>min</td><td>max</td><td>min</td><td>max</td><td>min</td><td>max</td><td>min</td><td>max</td></tr>
<tr><td>reference part</td><td>-4%</td><td>4%</td><td rowspan="3">-12%</td><td rowspan="3">12%</td><td rowspan="3">-2%</td><td rowspan="3">2%</td><td>-1%</td><td>3%</td><td>-0.1%</td><td>0.1%</td></tr>
<tr><td>part A</td><td>-10%</td><td>20%</td><td>-4%</td><td>2%</td><td>-0.2%</td><td>0.5%</td></tr>
<tr><td>part B</td><td>-10%</td><td>10%</td><td>-2%</td><td>2%</td><td>-0.1%</td><td>0.1%</td></tr>
</table>

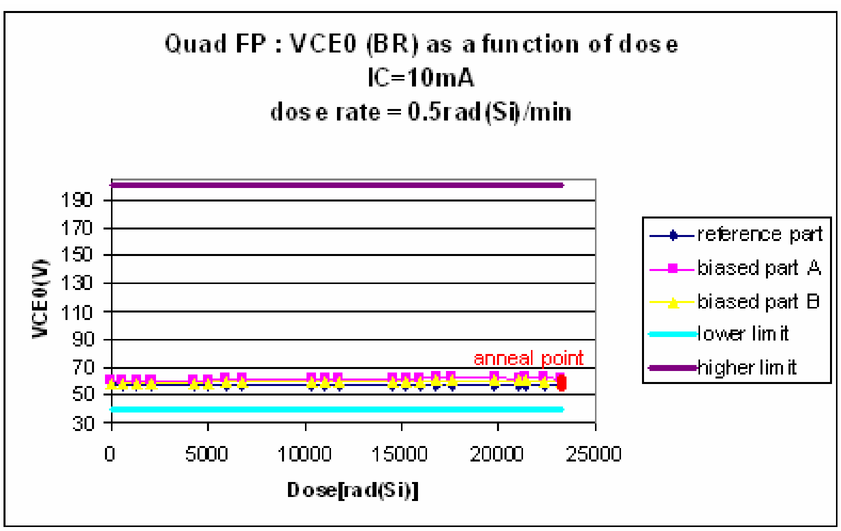

Figure 2: Quad FP collector-emitter voltage, open base, (IC=10mA) as a function of dose; gamma 0.5 rad(Si)/min

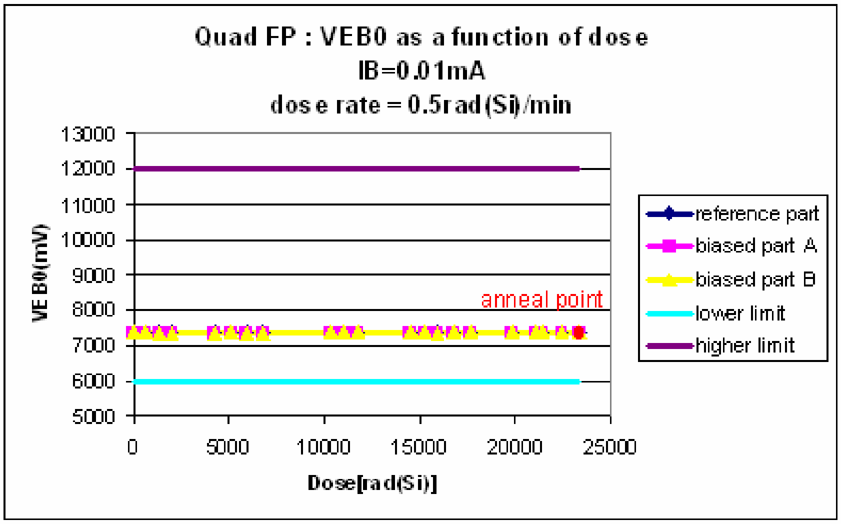

Figure 3: Quad FP emitter-base voltage, open collector, (IB=0.01mA) as a function of dose; gamma 0.5 rad(Si)/min

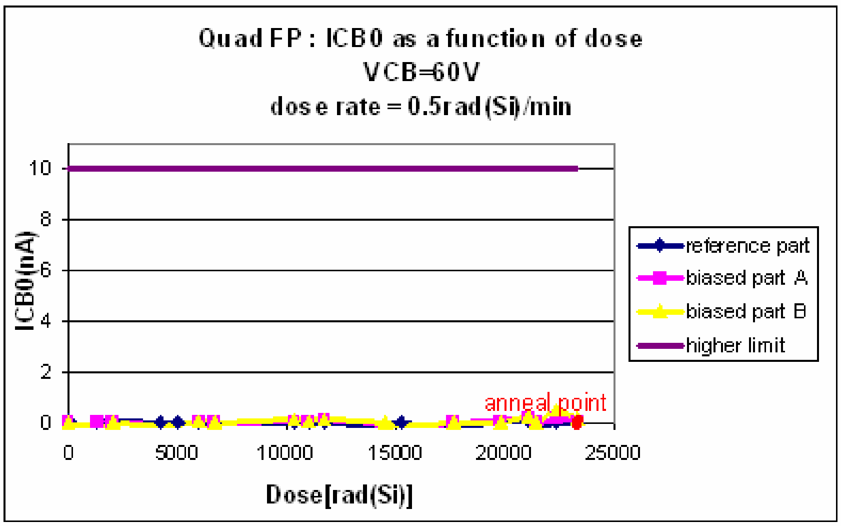

Figure 4: Quad FP collector cut-off current (VCB=60V) as a function of dose; gamma 0.5 rad(Si)/min

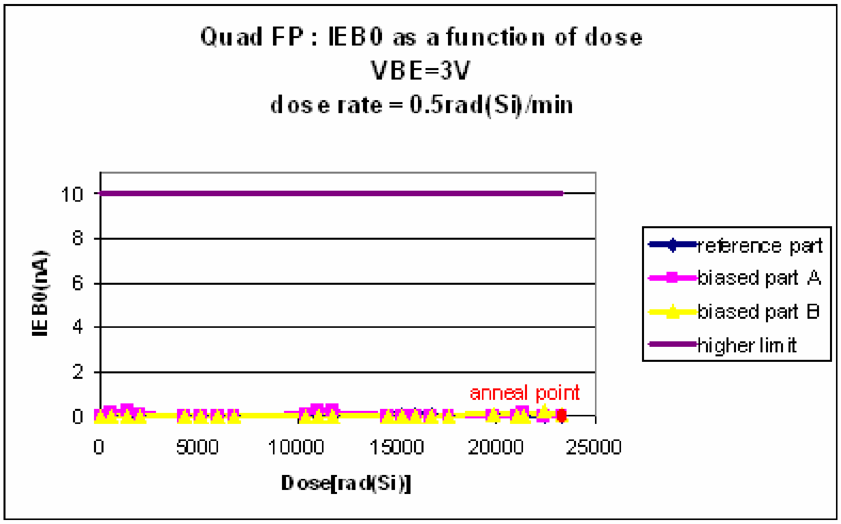

Figure 5: Quad FP emitter cut-off current (VBE=3V) as a function of dose; gamma 0.5 rad(Si)/min

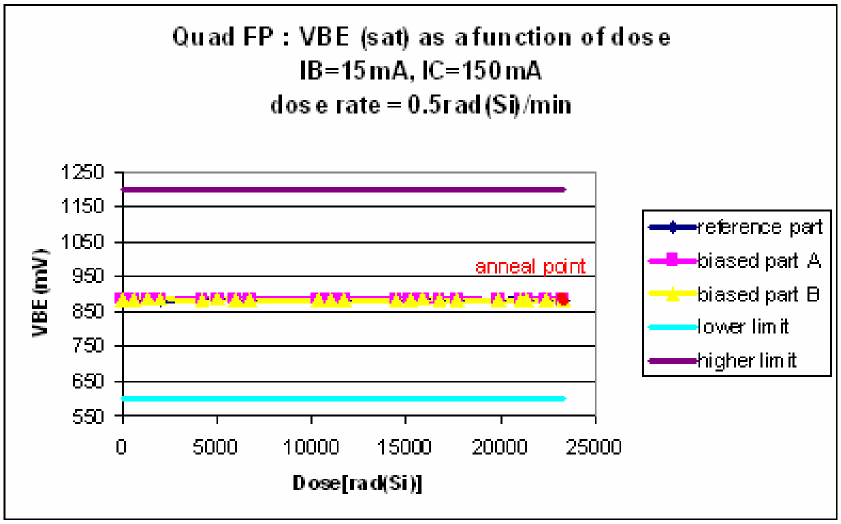

Figure 6: Quad FP base-emitter saturation voltage (IB=15mA, IC=150mA) as a function of dose; gamma 0.5 rad(Si)/min

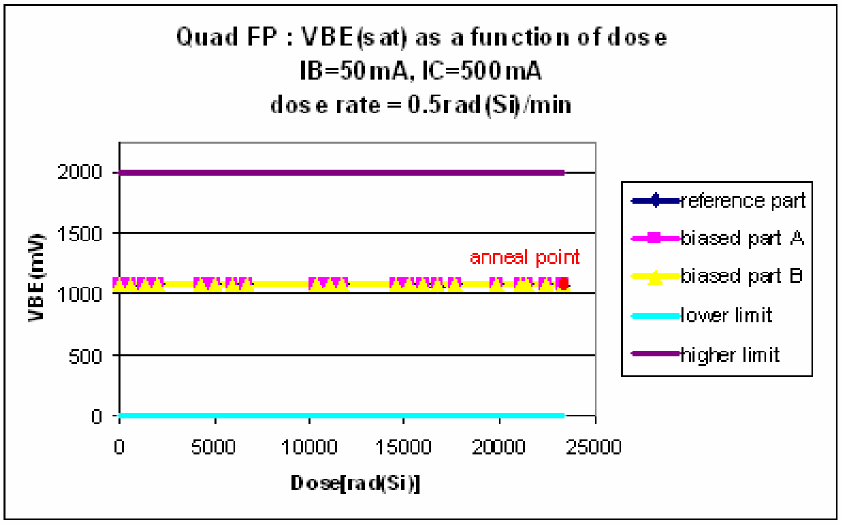

Figure 7: Quad FP base-emitter saturation voltage (IB=50mA, IC=500mA) as a function of dose; gamma 0.5 rad(Si)/min

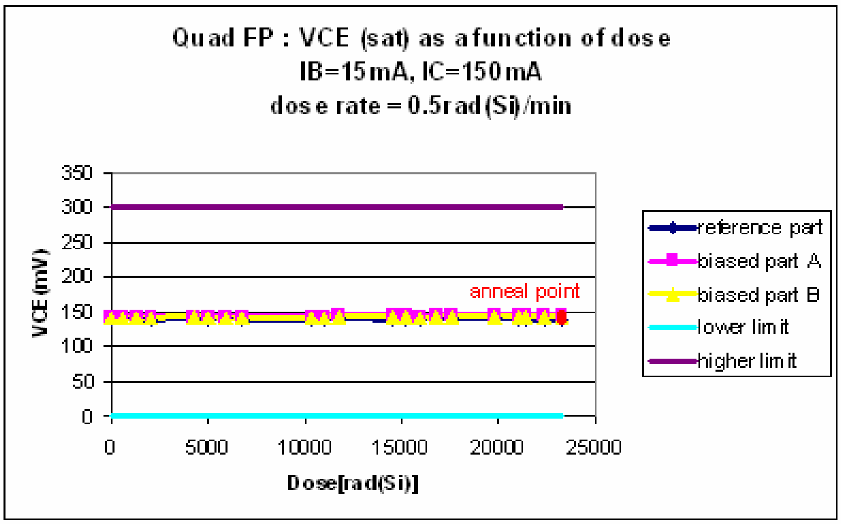

Figure 8: Quad FP collector-emitter saturation voltage (IB=15mA, IC=150mA) as a function of dose; gamma 0.5 rad(Si)/min

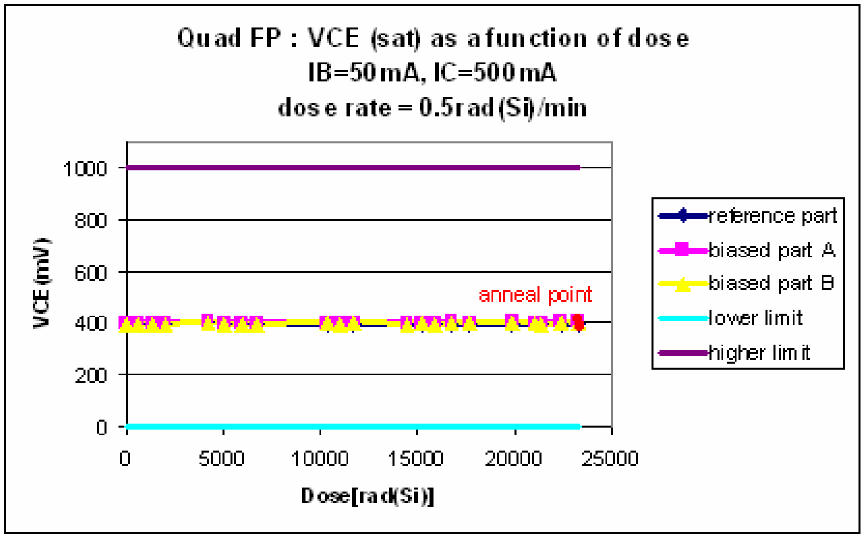

Figure 9: Quad FP collector-emitter saturation voltage (IB=50mA, IC=500mA) as a function of dose; gamma 0.5 rad(Si)/min

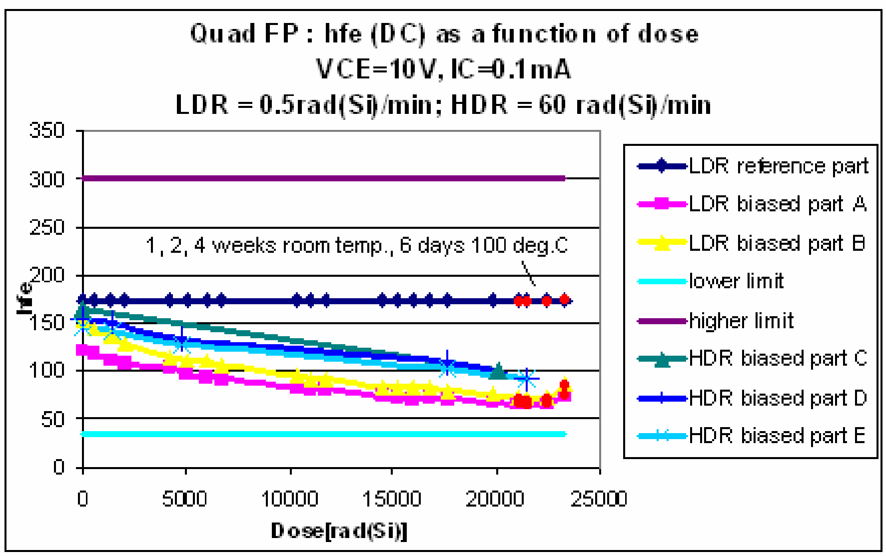

Figure 10: Quad FP DC current gain (VCE=10V, IC=0.1mA) as a function of dose; gamma 0.5 rad(Si)/min

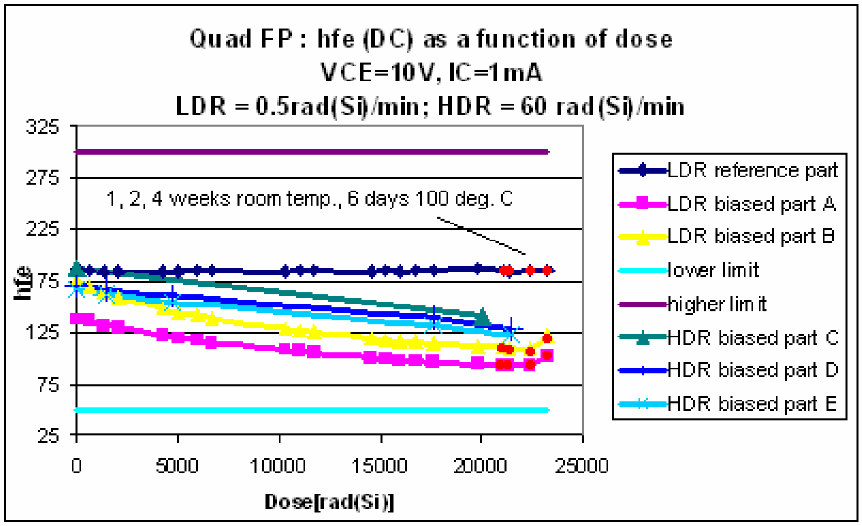

Figure 11: Quad FP DC current gain (VCE=10V, IC=1mA) as a function of dose; gamma 0.5 rad(Si)/min

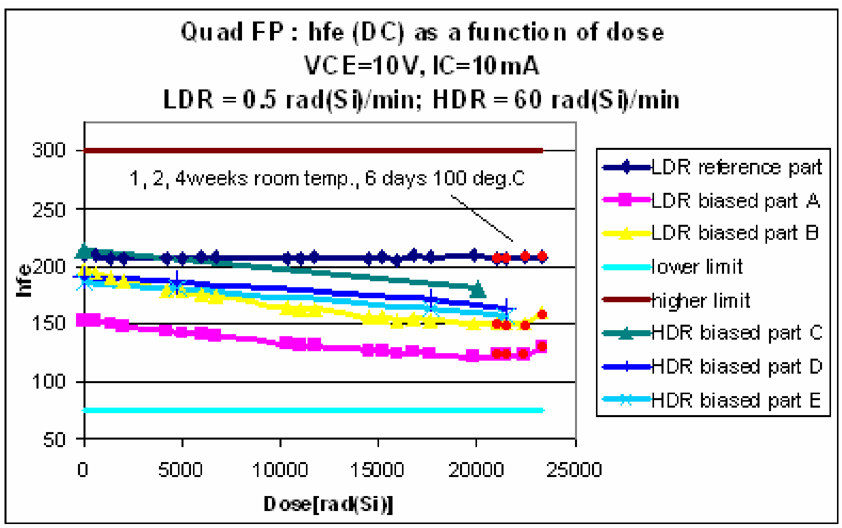

Figure 12: Quad FP DC current gain (VCE=10V, IC=10mA) as a function of dose; gamma 0.5 rad(Si)/min

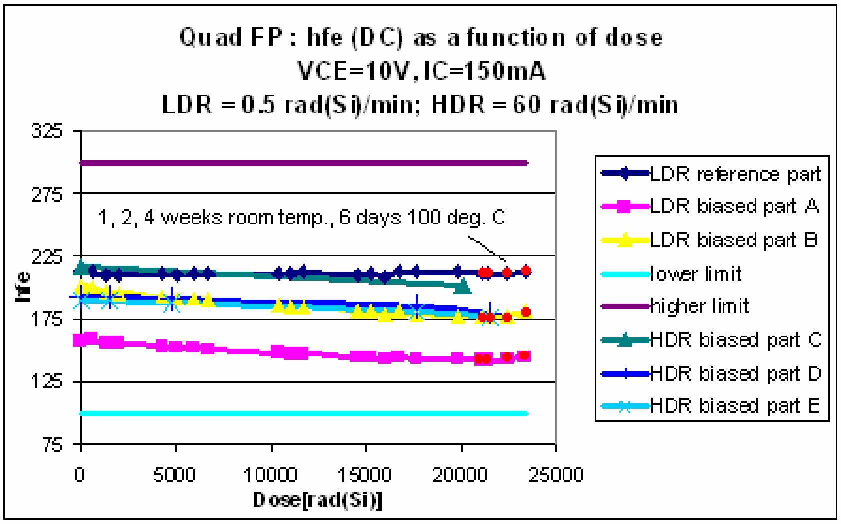

Figure 13: Quad FP DC current gain (VCE=10V, IC=150mA) as a function of dose; gamma 0.5 rad(Si)/min

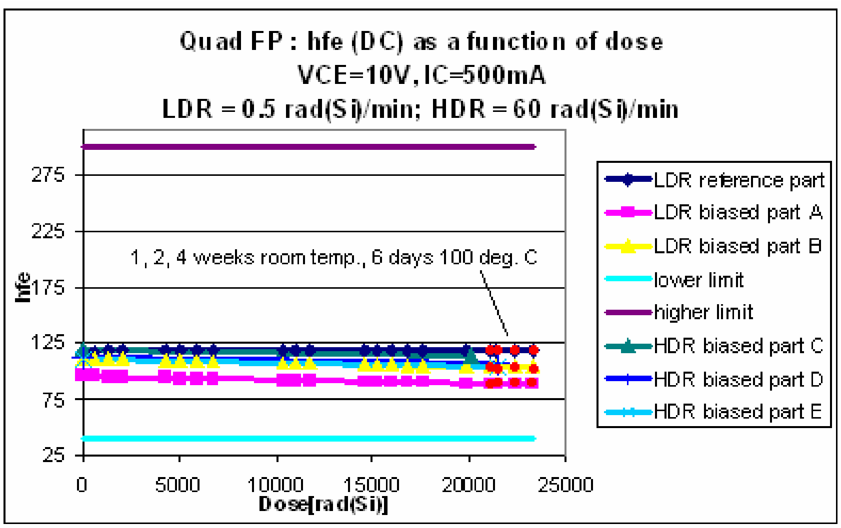

Figure 14: Quad FP DC current gain (VCE=10V, IC=500mA) as a function of dose; gamma 0.5 rad(Si)/min

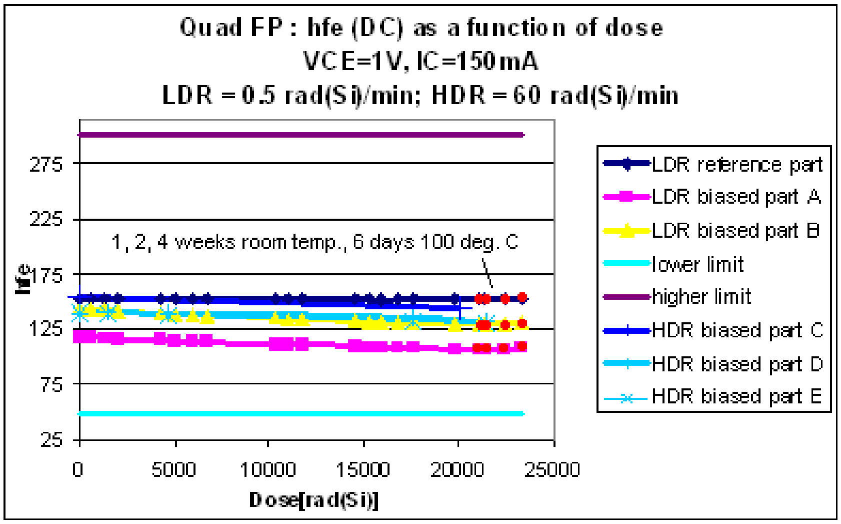

Figure 15: Quad FP DC current gain (VCE=1V, IC=150mA) as a function of dose; gamma 0.5 rad(Si)/min

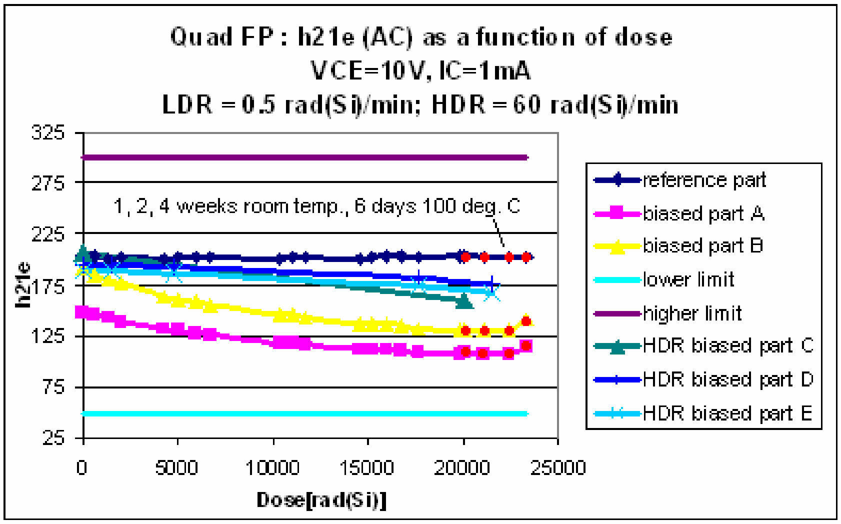

Figure 16: Quad FP hfe, AC current gain (VCE=10V, IC=1mA) as a function of dose; gamma 0.5 rad(Si)/min

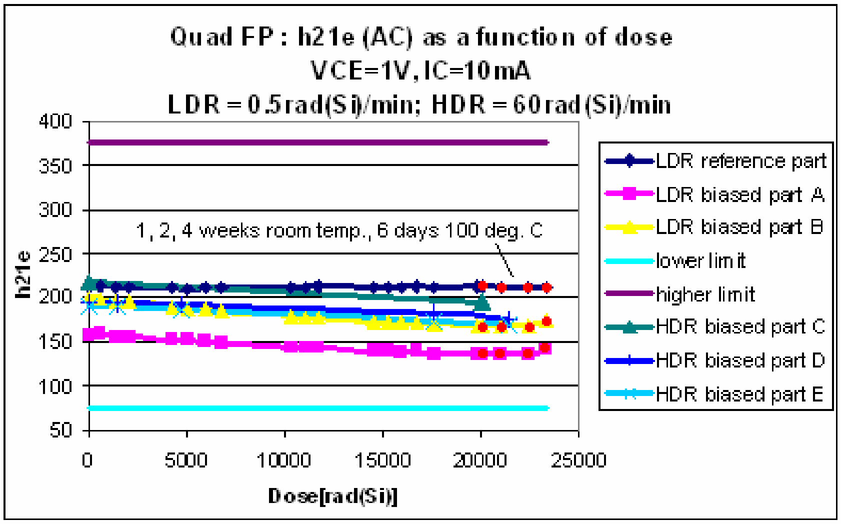

Figure 17: Quad FP hfe, AC current gain (VCE=10V, IC=10mA) as a function of dose; gamma 0.5 rad(Si)/min

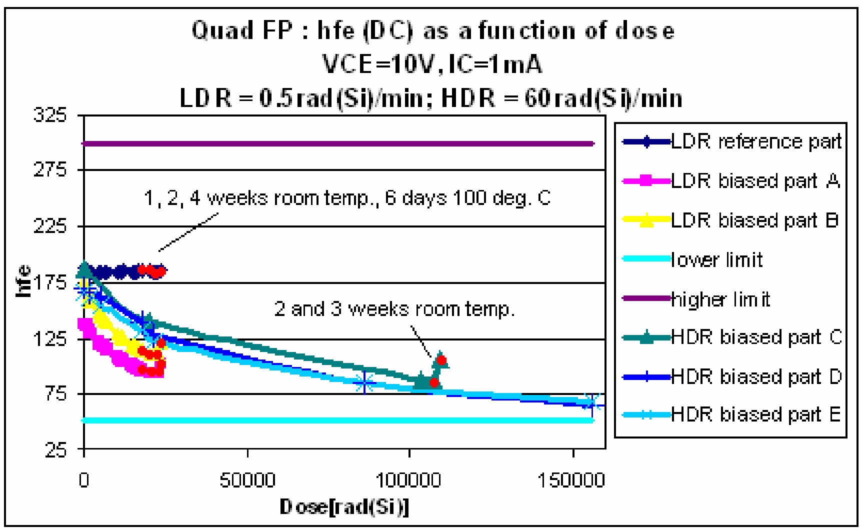

Figure 18: Quad FP DC current gain (VCE=10V, IC=1mA) as a function of dose; Low and High dose rates. High dose rate up to 156krad(Si).

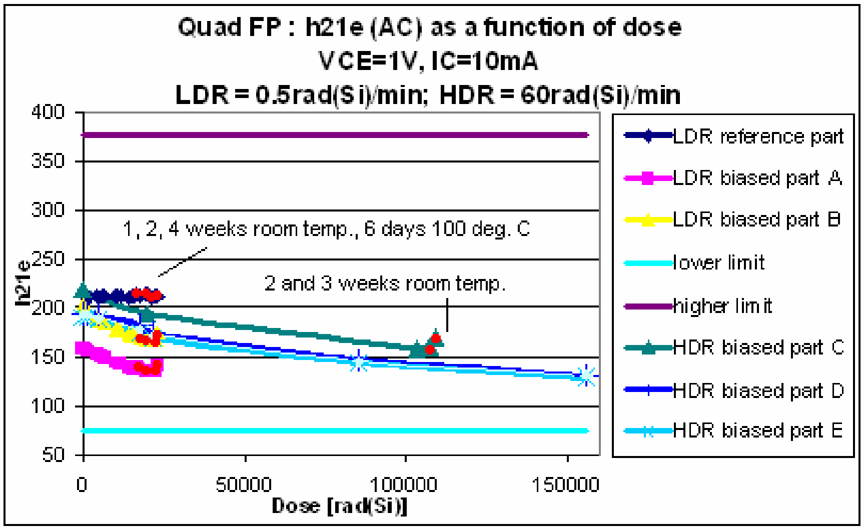

Figure 19: Quad FP hfe, AC current gain (VCE=10V, IC=10mA) as a function of dose; Low and High dose rates. High dose rate up to 156krad(Si).

5 CONCLUSION

Irradiation tests on the JANS2N6989U quad-NPN transistor device were performed to investigate the components susceptibility to ELDRS. Both low and high dose rate measurements were performed. The low dose rate measurements were performed to a total ionising dose of approximately 20krad(Si) while the high dose rate tests were performed to a total ionising dose level of approximately 156krad(Si). Vce, Veb, Icb, Ieb, Vbesat, Vcesat and hfe parameters were within their specified limits up to a total ionising dose of approximately 20krad(Si) for low dose rates and 156krad(Si) for high dose rates. Most parameters exhibited negligible drift for both low and high dose rates. Drifts were observed for parameters hfe for low and high dose rates.

There is no conclusive evidence of ELDRS for these devices. Largest parameter drift were observed for the hfe parameter. The impact of the hfe parameter drift needs to be assessed by the project.