PROTONS TEST REPORT

ESA study: “Survey of Critical Components for 150 kRad Power Systems”

ESTEC Contract N° 22831/09/NL/AF refers

Part Type : SOC2907A

Package : CCP-3

Description : PNP Small Signal Silicon transistors

Manufacturer: STMicroelectronics

Alter Technology Group Spain Purchase Order N° ATGSP-TL-09-JC-CO-9 dated 11/27/2009

Alter Technology Group Spain Project Manager: David NUNEZ

Hirex reference :	HRX/TID/0942	Issue : 01	Date :	June 03rd, 2011
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CHANGE RECORD

ISSUE	DATE	PAGE	DESCRIPTION OF CHANGES
01	June 03rd, 2011	All	Original Issue

PROTONS TEST REPORT
on
SOC2907A
PNP Small Signal Silicon transistors

From STMicroelectronics

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1 Introduction

In the scope of the ESA study: “Survey of Critical Components for 150 kRad Power Systems”, a protons test of the STMicroelectronics SOC2907A, PNP Small Signal Silicon transistors has been performed up to a total fluence of about 2E11 p/cm^2, in response to Alter Technology Group Spain purchase order reference ATGSP-TL-09-JC-CO-9 that refers to ESTEC contract N° 22831/09/NL/AF.

Displacement damage effects were investigated using 60 MeV protons energy. Devices were irradiated at UCL in Louvain - Belgium.

The purpose of this test was to characterize degradation due to proton displacement damage so a further mission analysis could determine their suitability for flight use. This test was conducted on samples provided by Alter Technology Group Spain.
Test has been performed in accordance with Hirex Engineering Radiation Test Plan HRX/SPE/0227 issue 2 dated 09/06/2011.

A complete set of electrical measurements together with graphical representation of measured parameters with respect to Equivalent Fluence levels received is provided.

2 Applicable and Reference Documents

2.1 Applicable Documents

- Hirex Engineering Radiation Test Plan: HRX/SPE/0227 issue 2 dated 09/06/2011
- Alter Technology Group Proposal: ATGSP-OF-648/2009 Issue 1
- Minutes of Meeting: MM-SRP-ATG-0001 dated 29/10/2009
- Hirex specification: Total Ionizing dose test general procedure.
- ESCC detail specification: 5202-001

2.2 Reference Documents

- STMicroelectronics datasheet: ID 15382 Rev 2, January 2010.

3 Test Samples

7 samples of the SOC2907A devices were tested (6 + 1 control sample).
Allocation of samples used for testing is provided in the following table. Serial numbers were arbitrarily defined by Hirex.

Serial Number	Samples Allocation
1	Control sample
2	Biased OFF
3	Biased OFF
4	Biased OFF
5	Biased OFF
6	Biased OFF
7	Biased OFF

Identification of the SOC2907A is given below:

Part Number: SOC2907ASW

Top Marking: -

Inspection lot: DOC01284

Date Code: -

4 Experimental Conditions

4.1 Radiation Source Description

The protons exposures were performed at the UCL facility in Louvain-la-Neuve - Belgium.
The Proton Irradiation facility (Light Ion irradiation Facility or LIF) was used for this experiment. The corresponding experimental set-up is shown in Figure 1.

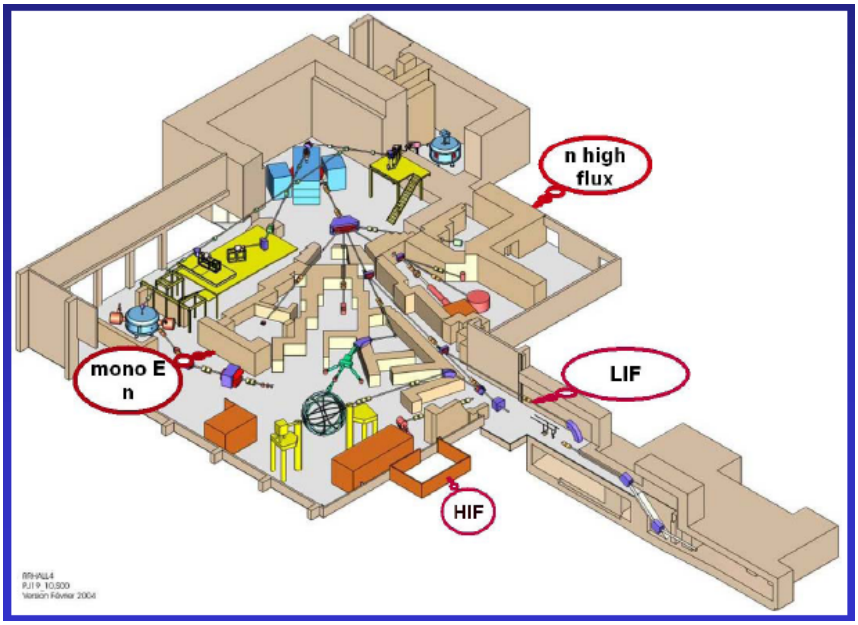


Figure 1 : LIF layout and typical experimental set-up

Light Ion irradiation Facility is characterized by the following beam parameters:
• Initial Proton Energies: 65 MeV;
• Energy Range: 9.3 – 62 MeV using energy degraders (See figure 2)
• Beam Flux at 62 MeV is between 10p/cm2/sec to 5E8 p/cm2/sec
• Irradiation Area: 8 cm diameter maximum

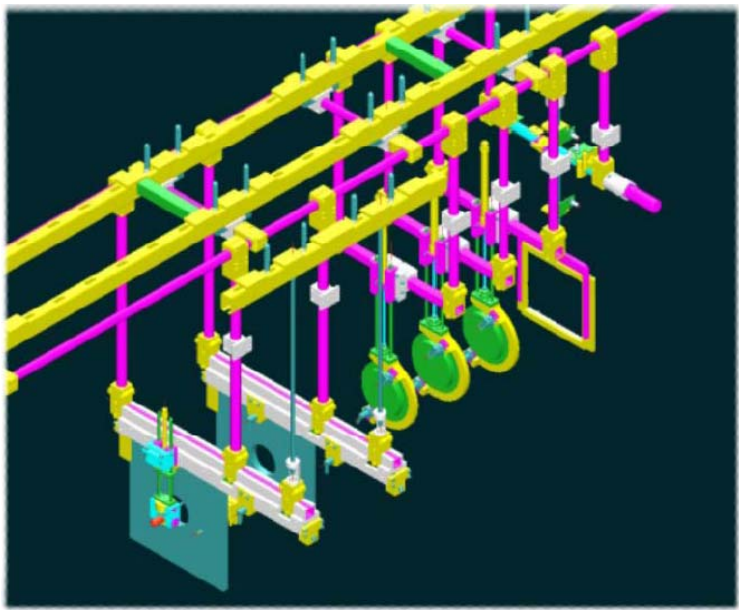


Figure 2: LIF Energy degraders

Irradiation conditions used for this test are provided in the following table:

Fluence Steps	Total Fluence	Flux	Equivalent Total Dose	T
p/cm² @60MeV	p/cm² @60MeV	p/cm²/s	Rad (Si)	°C
0	0		0	
2E+11	2E+11	5.00E+08	27.5E+3	25

4.2 Bias during Dose Exposures and Measurements conditions

4.2.1 Bias conditions

During exposures all samples were biased OFF with all pins connected to ground.

4.2.2 Electrical Measurements

Electrical parameters test program principle for SOC2907A is provided in Figure 3.

A HP4142 DC tester and a network analyzer HP8714ES were used to perform required measurements.

A dedicated test fixture and a test board were designed to ensure proper measurement conditions.

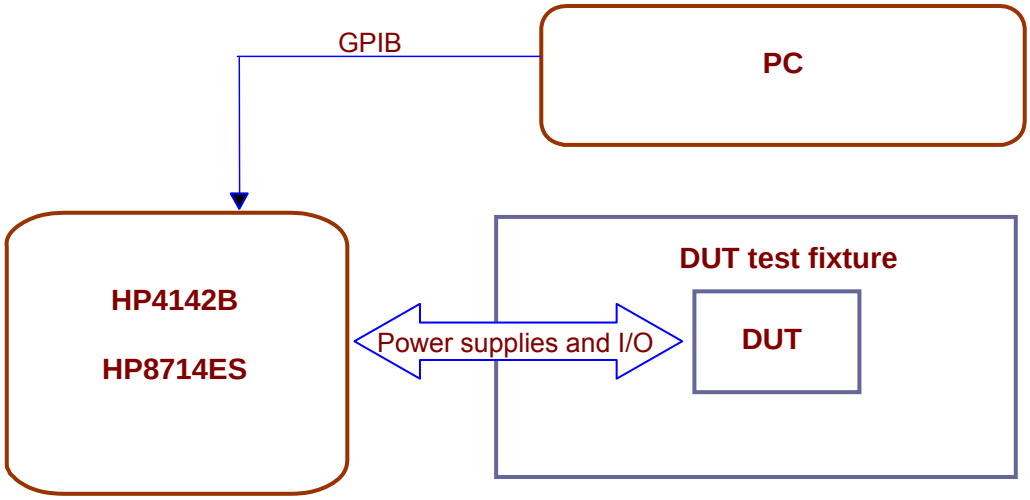


Figure 3 : SOC2907A test program principle

Electrical parameters test conditions and limits used for performing this test are given in Table 1.

Parameter	Description	Conditions	Spec		Unit
			Min	Max	
I_{CBO}	Collector-Base cut-off current	V_{CB} = -60V	-10	-	nA
I_{CEO}	Collector-Emitter cut-off current	V_{CE} = -60V	-10	-	nA
$V_{(BR)CBO}$	Collector-Base breakdown voltage	I_C = -10µA	-	-60	V
$V_{(BR)CEO}$	Collector-Emitter breakdown voltage	I_C = -10mA Note 1	-	-60	V
$V_{(BR)EBO}$	Emitter-Base breakdown voltage	I_E = -10µA	-	-5	V
$V_{CE(SAT)}$	Collector-Emitter saturation voltage	I_C = -150mA, I_B = -15mA Note 1	-0.4	-	V
$V_{BE(SAT)}$	Base-Emitter saturation voltage	I_C = -150mA, I_B = -15mA Note 1	-1.3	-	V
H_{FE1}	DC current gain	I_C = -100µA, V_{CE} = -10V Note 1	75	-	-
H_{FE2}	DC current gain	I_C = -1mA, V_{CE} = -10V Note 1	100	-	-
H_{FE3}	DC current gain	I_C = -10mA, V_{CE} = -10V Note 1	100	-	-
H_{FE4}	DC current gain	I_C = -150mA, V_{CE} = -10V Note 1	100	300	-
F_T	Gain Bandwidth Product	I_C = -20mA, V_{CE} = -20V	200	-	MHz

Note 1: Pulse measurement: Pulse Width ≤ 300µs, duty cycle 1%

Table 1 : Measured electrical parameters

5 Conclusion

A proton displacement damage test was carried out by Hirex Engineering under Alter Technology Group Spain contract on the STMicroelectronics SOC2907A PNP Small Signal Silicon transistors in CCP-3 package.

Each device was exposed at room temperature to a protons flux of 60 MeV incident energy up to a total fluence of 2E+11p/cm².

A summary of failed parameters is provided in the following table.
Parameters not listed remained within specification limits all along testing.
Detail test results are presented in the following section.

Parameters	Failure Level between :	Comments
ICEO	0 & 2E+11 p/cm²	

Table 2 : Summary of failed parameters

6 Test Results

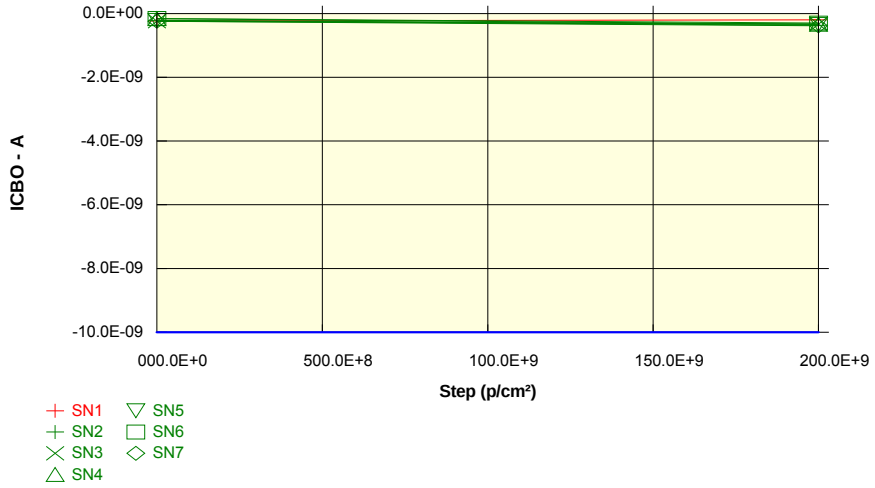
Test results including tables and graphics are provided in this section for each measured parameter.

Parameter measurements values are plotted versus Equivalent Fluence levels for 60 MeV incident energy protons. Fluences are expressed in protons/cm^2 in Silicon.

For each parameter, a drift calculation table is provided computing the drift between a given exposure step with respect to initial readings:

$$\Delta\text{(Parameter value)}=\text{(Parameter value}_{POSTRAD}\text{)} - \text{(Parameter value}_{PRERAD}\text{)}$$

Test conditions : PROTONS
Parameter : Collector-Base cut-off current : ICBO
Vcb = -60V
Unit : A
Spec Limit Min : -10.0E-09
Spec limits are represented in bold lines on the graphic.



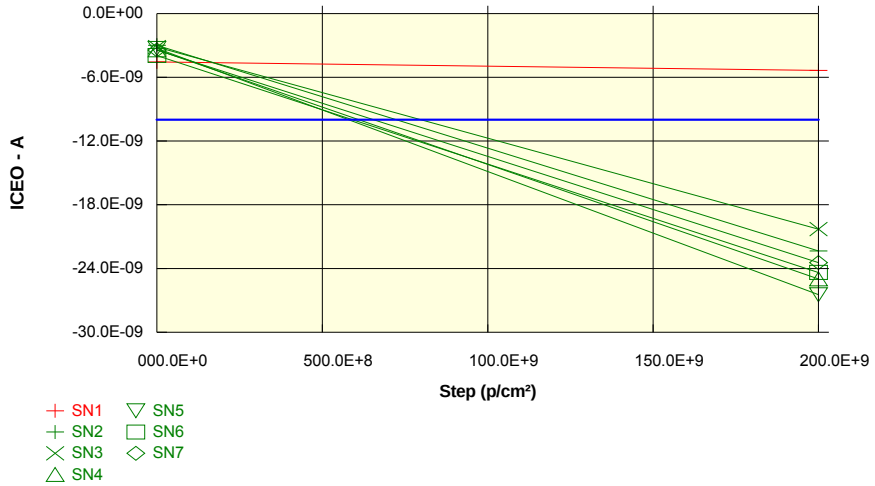
Measurements

ICBO	0 p/cm²	2E+11 p/cm²
SN1_REF	-229.4E-12	-194.7E-12
OFF samples		
SN2	-222.4E-12	-364.3E-12
SN3	-240.8E-12	-330.0E-12
SN4	-162.1E-12	-332.0E-12
SN5	-213.4E-12	-338.5E-12
SN6	-154.0E-12	-298.0E-12
SN7	-241.2E-12	-383.5E-12
Statistics		
Min	-241.2E-12	-383.5E-12
Max	-154.0E-12	-298.0E-12
Average	-205.6E-12	-341.0E-12
Sigma	35.1E-12	27.1E-12

Drift Calculation

ICBO	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-141.88E-12
SN3	-	-89.16E-12
SN4	-	-169.92E-12
SN5	-	-125.08E-12
SN6	-	-144.02E-12
SN7	-	-142.26E-12
Average	-	-135.39E-12
Sigma	-	24.49E-12

Test conditions : PROTONS
Parameter : Collector-Emitter cut-off current : ICEO
Vce = -60V
Unit : A
Spec Limit Min : -10.0E-09
Spec limits are represented in bold lines on the graphic.



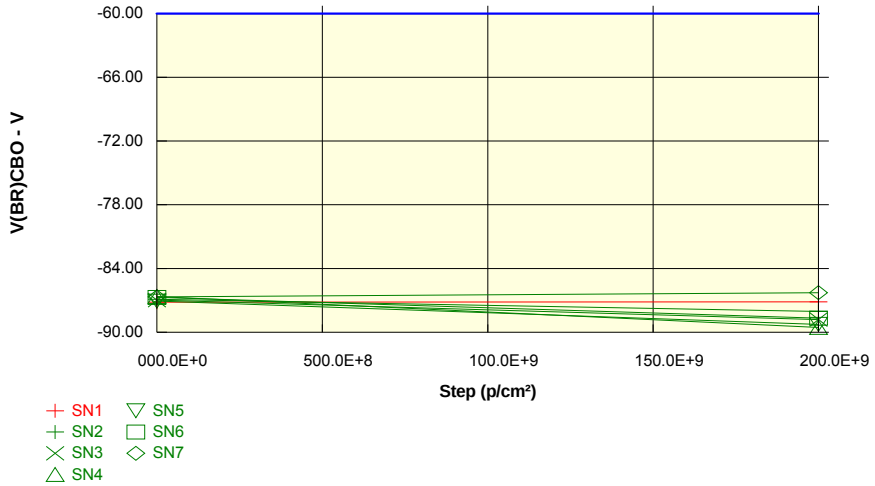
Measurements

ICEO	0 p/cm²	2E+11 p/cm²
SN1_REF	-4.5E-09	-5.3E-09
OFF samples		
SN2	-3.0E-09	-22.3E-09
SN3	-3.2E-09	-20.3E-09
SN4	-3.4E-09	-25.0E-09
SN5	-3.3E-09	-26.5E-09
SN6	-3.9E-09	-24.4E-09
SN7	-3.4E-09	-23.4E-09
Statistics		
Min	-3.9E-09	-26.5E-09
Max	-3.0E-09	-20.3E-09
Average	-3.4E-09	-23.6E-09
Sigma	299.9E-12	2.0E-09

Drift Calculation

ICEO	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-19.36E-09
SN3	-	-17.14E-09
SN4	-	-21.56E-09
SN5	-	-23.19E-09
SN6	-	-20.43E-09
SN7	-	-20.00E-09
Average	-	-20.28E-09
Sigma	-	1.87E-09

Test conditions : PROTONS
Parameter : Collector-Base breakdown voltage : V(BR)CBO
Ic = -10µA
Unit : V
Spec Limit Max : -60.00
Spec limits are represented in bold lines on the graphic.



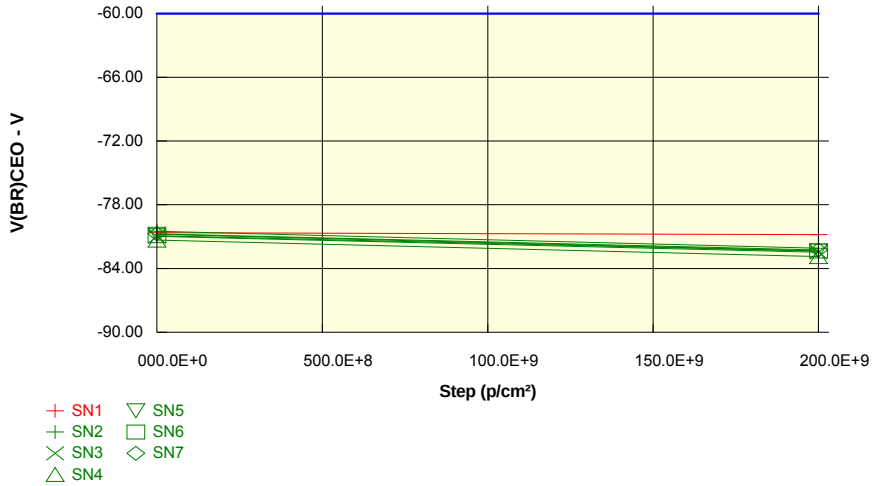
Measurements

V(BR)CBO	0 p/cm²	2E+11 p/cm²
SN1_REF	-87.16	-87.14
OFF samples		
SN2	-86.90	-88.06
SN3	-86.98	-88.81
SN4	-86.64	-89.56
SN5	-87.07	-89.26
SN6	-86.73	-88.68
SN7	-86.66	-86.27
Statistics		
Min	-87.07	-89.56
Max	-86.64	-86.27
Average	-86.83	-88.44
Sigma	0.16	1.08

Drift Calculation

V(BR)CBO	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-1.16E+00
SN3	-	-1.83E+00
SN4	-	-2.92E+00
SN5	-	-2.19E+00
SN6	-	-1.95E+00
SN7	-	396.00E-03
Average	-	-1.61E+00
Sigma	-	1.04E+00

Test conditions : PROTONS
Parameter : Collector-Emitter breakdown voltage : V(BR)CEO
Ic = -10mA (Pulse width 300µs. Duty cycle 1%)
Unit : V
Spec Limit Max : -60.00
Spec limits are represented in bold lines on the graphic.



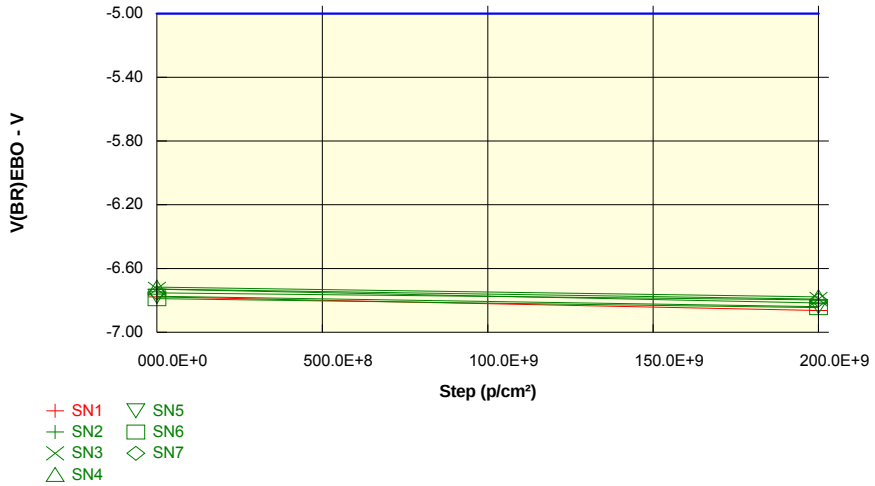
Measurements

V(BR)CEO	0 p/cm²	2E+11 p/cm²
SN1_REF	-80.63	-80.81
OFF samples		
SN2	-80.50	-82.09
SN3	-80.98	-82.46
SN4	-81.32	-82.88
SN5	-80.77	-82.34
SN6	-80.92	-82.36
SN7	-80.74	-82.25
Statistics		
Min	-81.32	-82.88
Max	-80.50	-82.09
Average	-80.87	-82.40
Sigma	0.25	0.25

Drift Calculation

V(BR)CEO	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-1.59E+00
SN3	-	-1.48E+00
SN4	-	-1.56E+00
SN5	-	-1.57E+00
SN6	-	-1.44E+00
SN7	-	-1.51E+00
Average	-	-1.52E+00
Sigma	-	52.10E-03

Test conditions : PROTONS
Parameter : Emitter-Base breakdown voltage : V(BR)EBO
Ie = -10µA
Unit : V
Spec Limit Max : -5.00
Spec limits are represented in bold lines on the graphic.



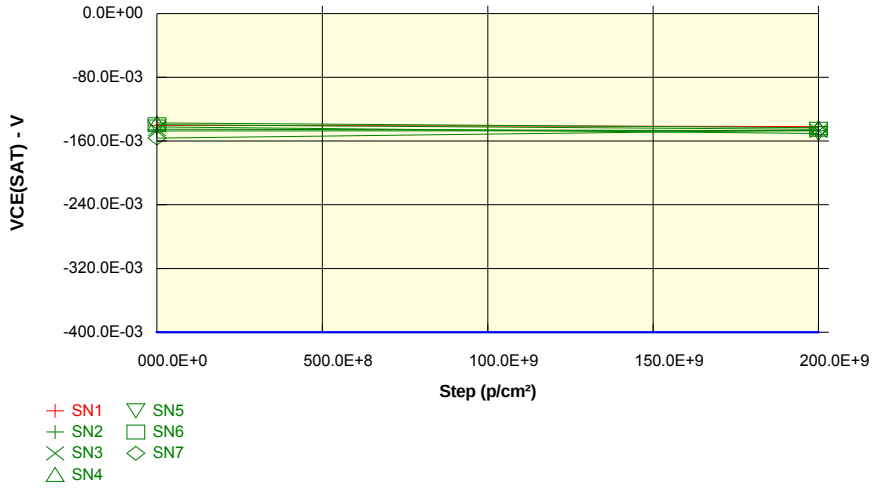
Measurements

V(BR)EBO	0 p/cm²	2E+11 p/cm²
SN1_REF	-6.78	-6.86
OFF samples		
SN2	-6.73	-6.82
SN3	-6.73	-6.79
SN4	-6.72	-6.78
SN5	-6.78	-6.84
SN6	-6.79	-6.85
SN7	-6.75	-6.80
Statistics		
Min	-6.79	-6.85
Max	-6.72	-6.78
Average	-6.75	-6.81
Sigma	0.03	0.02

Drift Calculation

V(BR)EBO	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-86.40E-03
SN3	-	-64.00E-03
SN4	-	-61.20E-03
SN5	-	-64.00E-03
SN6	-	-56.80E-03
SN7	-	-45.60E-03
Average	-	-63.00E-03
Sigma	-	12.21E-03

Test conditions : PROTONS
Parameter : Collector-Emitter saturation voltage : VCE(SAT)
Ic = -150mA ; Ib = -15mA (Pulse width 300µs. Duty cycle 1%)
Unit : V
Spec Limit Min : -400.0E-03
Spec limits are represented in bold lines on the graphic.



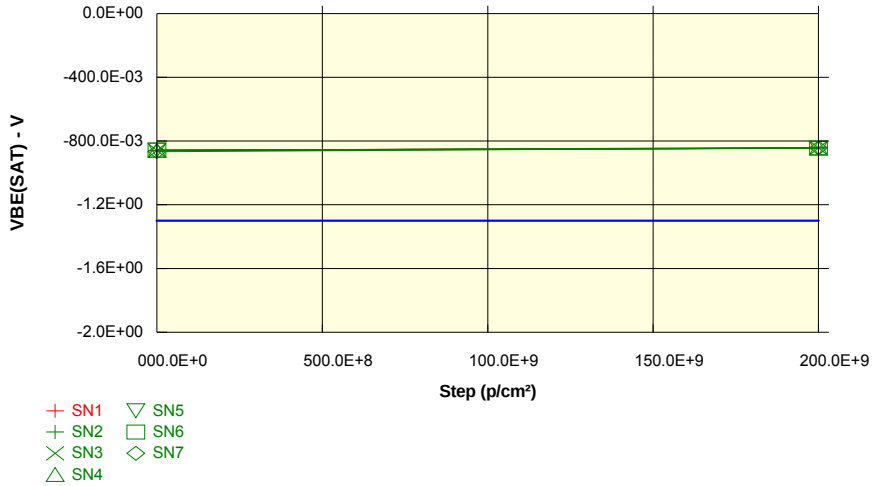
Measurements

VCE(SAT)	0 p/cm²	2E+11 p/cm²
SN1_REF	-140.1E-03	-141.8E-03
OFF samples		
SN2	-147.2E-03	-147.1E-03
SN3	-145.1E-03	-147.2E-03
SN4	-137.1E-03	-143.2E-03
SN5	-142.4E-03	-150.6E-03
SN6	-139.4E-03	-145.3E-03
SN7	-156.3E-03	-146.2E-03
Statistics		
Min	-156.3E-03	-150.6E-03
Max	-137.1E-03	-143.2E-03
Average	-144.6E-03	-146.6E-03
Sigma	6.2E-03	2.2E-03

Drift Calculation

VCE(SAT)	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	120.00E-06
SN3	-	-2.04E-03
SN4	-	-6.12E-03
SN5	-	-8.20E-03
SN6	-	-5.84E-03
SN7	-	10.04E-03
Average	-	-2.01E-03
Sigma	-	6.05E-03

Test conditions : PROTONS
Parameter : Base-Emitter saturation voltage : VBE(SAT)
Ic = -150mA ; Ib = -15mA (Pulse width 300µs. Duty cycle 1%)
Unit : V
Spec Limit Min : -1.3E+00
Spec limits are represented in bold lines on the graphic.



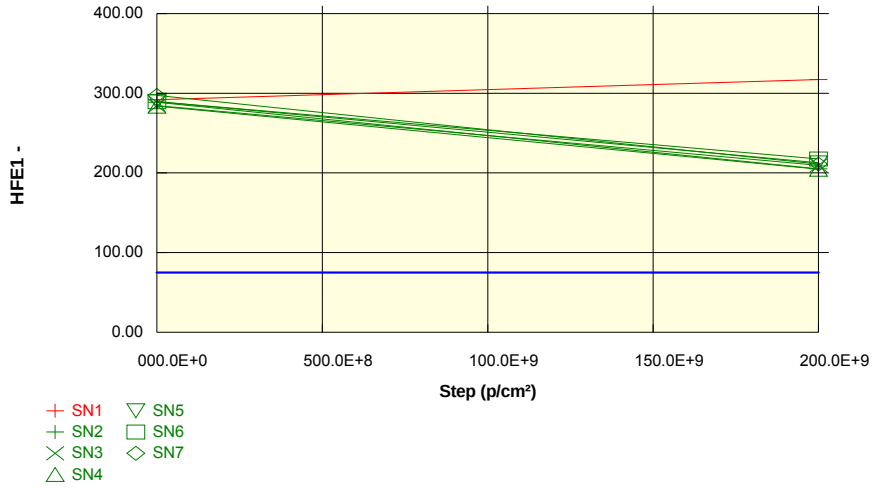
Measurements

VBE(SAT)	0 p/cm²	2E+11 p/cm²
SN1_REF	-858.0E-03	-840.1E-03
OFF samples		
SN2	-862.0E-03	-844.6E-03
SN3	-859.7E-03	-843.5E-03
SN4	-857.0E-03	-842.8E-03
SN5	-856.8E-03	-845.8E-03
SN6	-856.8E-03	-844.6E-03
SN7	-867.0E-03	-843.0E-03
Statistics		
Min	-867.0E-03	-845.8E-03
Max	-856.8E-03	-842.8E-03
Average	-859.9E-03	-844.0E-03
Sigma	3.7E-03	1.0E-03

Drift Calculation

VBE(SAT)	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	17.40E-03
SN3	-	16.20E-03
SN4	-	14.16E-03
SN5	-	11.04E-03
SN6	-	12.16E-03
SN7	-	24.08E-03
Average	-	15.84E-03
Sigma	-	4.28E-03

Test conditions : PROTONS
Parameter : DC current gain : HFE1
Ic = -100µA ; Vce = -10V (Pulse width 300µs. Duty cycle 1%)
Unit :
Spec Limit Min : 75.00
Spec limits are represented in bold lines on the graphic.



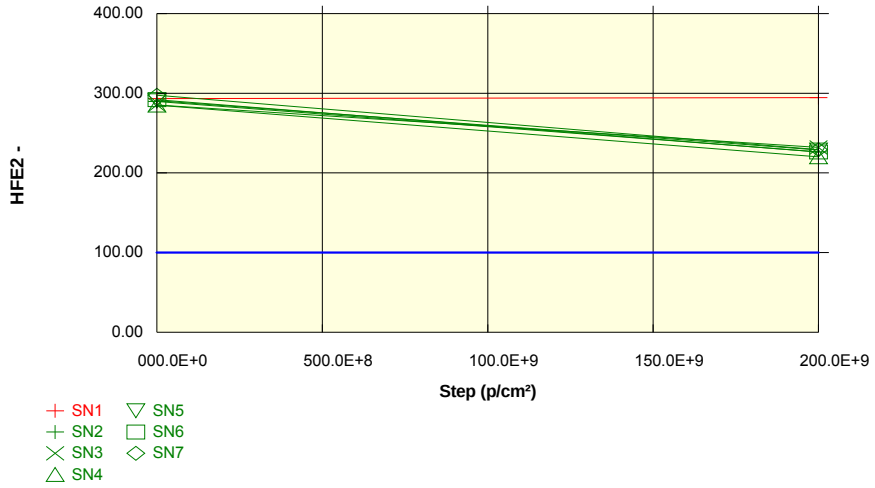
Measurements

HFE1	0 p/cm²	2E+11 p/cm²
SN1_REF	291.88	317.22
OFF samples		
SN2	288.73	205.19
SN3	284.48	209.39
SN4	283.83	204.65
SN5	289.36	212.58
SN6	289.47	217.53
SN7	297.36	211.05
Statistics		
Min	283.83	204.65
Max	297.36	217.53
Average	288.87	210.07
Sigma	4.42	4.41

Drift Calculation

HFE1	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	1.41E-03
SN3	-	1.26E-03
SN4	-	1.36E-03
SN5	-	1.25E-03
SN6	-	1.14E-03
SN7	-	1.38E-03
Average	-	1.30E-03
Sigma	-	91.98E-06

Test conditions : PROTONS
Parameter : DC current gain : HFE2
Ic = -1mA ; Vce = -10V (Pulse width 300µs. Duty cycle 1%)
Unit :
Spec Limit Min : 100.00
Spec limits are represented in bold lines on the graphic.



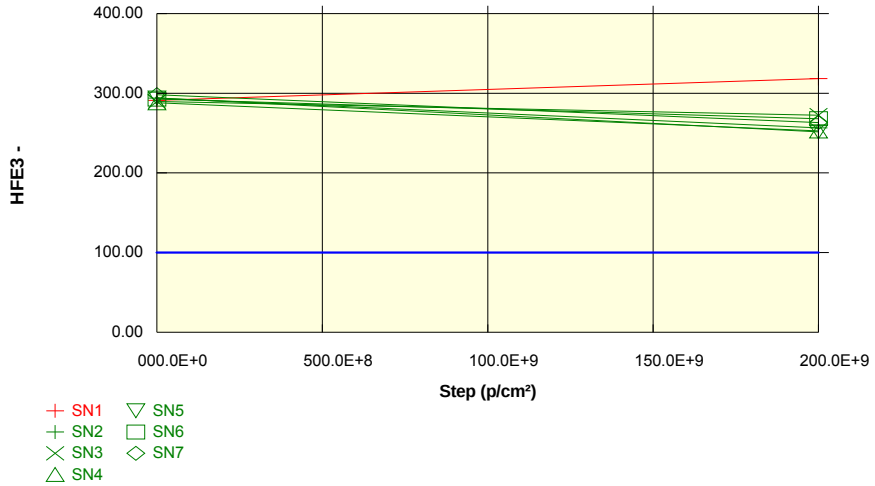
Measurements

HFE2	0 p/cm²	2E+11 p/cm²
SN1_REF	293.43	294.46
OFF samples		
SN2	289.75	226.55
SN3	285.41	231.98
SN4	284.99	220.36
SN5	290.64	228.86
SN6	292.05	226.27
SN7	297.39	229.16
Statistics		
Min	284.99	220.36
Max	297.39	231.98
Average	290.04	227.19
Sigma	4.19	3.59

Drift Calculation

HFE2	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	962.92E-06
SN3	-	807.08E-06
SN4	-	1.03E-03
SN5	-	928.86E-06
SN6	-	995.56E-06
SN7	-	1.00E-03
Average	-	954.10E-06
Sigma	-	72.89E-06

Test conditions : PROTONS
Parameter : DC current gain : HFE3
Ic = -10mA ; Vce = -10V (Pulse width 300µs. Duty cycle 1%)
Unit :
Spec Limit Min : 100.00
Spec limits are represented in bold lines on the graphic.



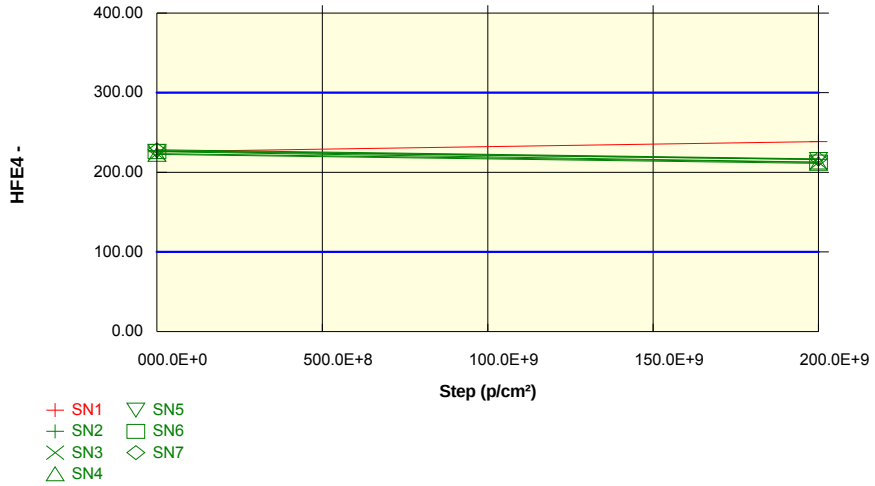
Measurements

HFE3	0 p/cm²	2E+11 p/cm²
SN1_REF	291.11	318.53
OFF samples		
SN2	293.92	256.51
SN3	289.63	272.52
SN4	288.04	252.59
SN5	294.11	251.48
SN6	292.59	268.01
SN7	298.09	263.20
Statistics		
Min	288.04	251.48
Max	298.09	272.52
Average	292.73	260.72
Sigma	3.26	7.83

Drift Calculation

HFE3	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	496.19E-06
SN3	-	216.73E-06
SN4	-	487.28E-06
SN5	-	576.27E-06
SN6	-	313.44E-06
SN7	-	444.79E-06
Average	-	422.45E-06
Sigma	-	121.11E-06

Test conditions : PROTONS
Parameter : DC current gain : HFE4
Ic = -150mA ; Vce = -10V (Pulse width 300µs. Duty cycle 1%)
Unit :
Spec Limit Min : 100.00
Spec Limit Max : 300.00
Spec limits are represented in bold lines on the graphic.



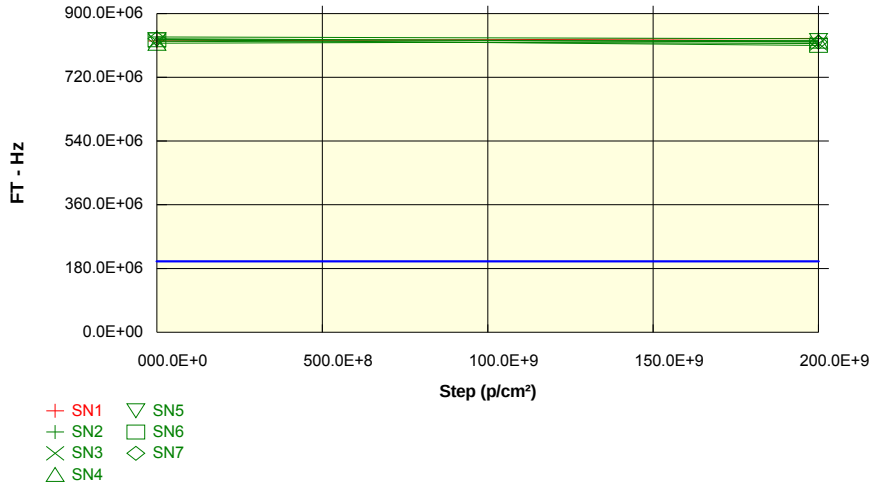
Measurements

HFE4	0 p/cm²	2E+11 p/cm²
SN1_REF	225.92	238.60
OFF samples		
SN2	227.35	216.31
SN3	223.48	212.47
SN4	222.57	211.35
SN5	226.43	216.15
SN6	225.97	212.95
SN7	228.21	216.85
Statistics		
Min	222.57	211.35
Max	228.21	216.85
Average	225.67	214.35
Sigma	2.01	2.16

Drift Calculation

HFE4	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	224.40E-06
SN3	-	232.01E-06
SN4	-	238.71E-06
SN5	-	209.93E-06
SN6	-	270.64E-06
SN7	-	229.58E-06
Average	-	234.21E-06
Sigma	-	18.53E-06

Test conditions : PROTONS
Parameter : Gain bandwidth product : FT
Ic = -20mA ; Vce = -20V
Unit : Hz
Spec Limit Min : 200.0E+06
Spec limits are represented in bold lines on the graphic.



Measurements

FT	0 p/cm²	2E+11 p/cm²
SN1_REF	822.2E+06	829.9E+06
OFF samples		
SN2	833.9E+06	829.3E+06
SN3	821.9E+06	815.1E+06
SN4	816.4E+06	822.1E+06
SN5	826.2E+06	823.8E+06
SN6	826.0E+06	810.2E+06
SN7	829.1E+06	819.4E+06
Statistics		
Min	816.4E+06	810.2E+06
Max	833.9E+06	829.3E+06
Average	825.6E+06	820.0E+06
Sigma	5.5E+06	6.1E+06

Drift Calculation

FT	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-4.60E+06
SN3	-	-6.78E+06
SN4	-	5.66E+06
SN5	-	-2.47E+06
SN6	-	-15.82E+06
SN7	-	-9.68E+06
Average	-	-5.62E+06
Sigma	-	6.58E+06