PROTONS TEST REPORT

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

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

Part Type : SOC3700SW

Package : CCP-3

Description : Low Power NPN Bipolar 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/0944	Issue : 01	Date :	June 06th, 2011
Written by :	G. VIDAL	Technician		
Approved by :	O.PERROTIN	Study Manager		
Authorized by:	J.F. PASCAL	Technical Manager		

CHANGE RECORD

ISSUE	DATE	PAGE	DESCRIPTION OF CHANGES
01	June 06th, 2011	All	Original Issue

PROTONS TEST REPORT
on
SOC3700SW
Low Power NPN Bipolar transistors

From STMicroelectronics

TABLE OF CONTENTS

List of figures:

List of Tables:

1 Introduction

In the scope of the ESA study: “Survey of Critical Components for 150 kRad Power Systems”, a protons test of the STMicroelectronics SOC3700SW, Low Power NPN Bipolar 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/0229 issue 3 dated 09/21/2010.

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

2 Applicable and Reference Documents

2.1 Applicable Documents

- Hirex Engineering Radiation Test Plan: HRX/SPE/0229 issue 3 dated 09/21/2010
- 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: 5201-004

2.2 Reference Documents

- STMicroelectronics datasheet: Doc ID 15354 Rev 2, January 2010.

3 Test Samples

7 samples of the SOC3700SW 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 SOC3700SW is given below:

Part Number: SOC3700SW

Top Marking: -

Inspection lot: DOC01285

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.

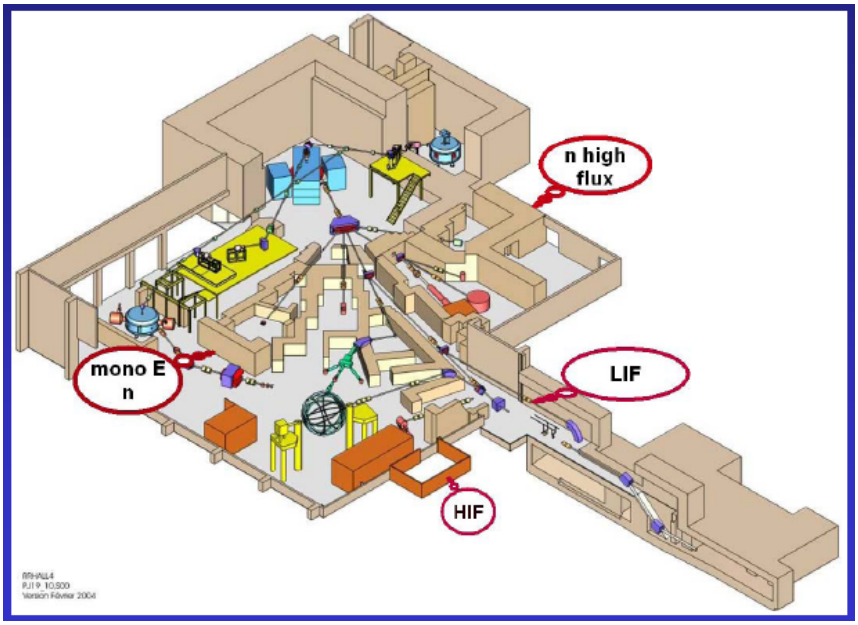


Figure 1 : LIF layout and typical experimental set-up

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

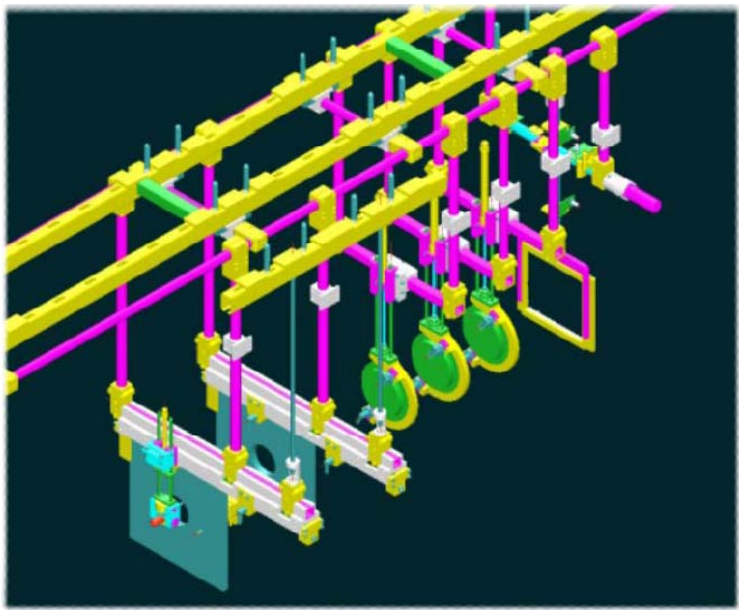


Figure 2: LIF Energy degraders

The 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 SOC3700SW 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.

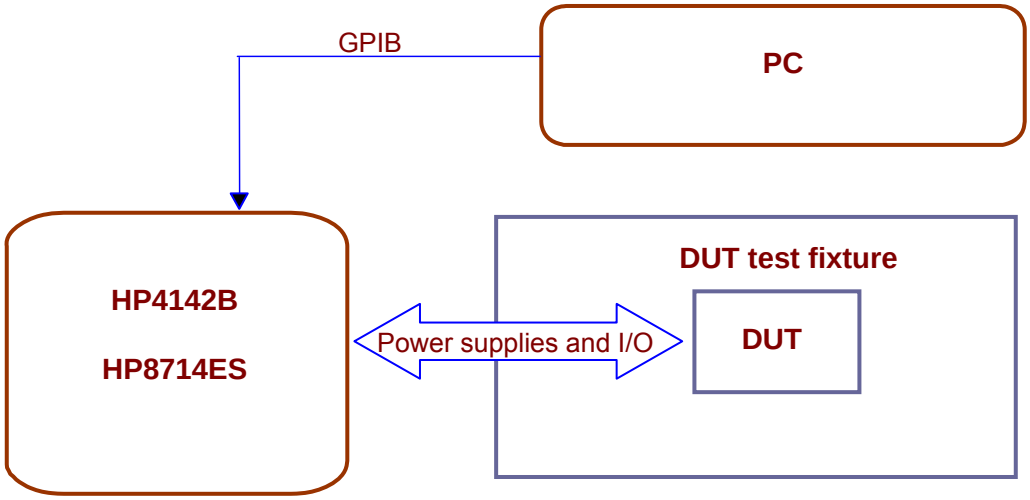


Figure 3 : SOC3700SW test program principle

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} = 90V	-	10	nA
I_{CEO}	Collector-Emitter cut-off current	V_{CE} = 80V	-	10	nA
I_{EBO}	Emitter-Base cut-off current	V_{EB} = 5V	-	10	nA
$V_{(BR)CBO}$	Collector-Base breakdown voltage	I_C = 100µA	140	-	V
$V_{(BR)CEO}$	Collector-Emitter breakdown voltage, Note 1	I_C = 30mA	80	-	V
$V_{(BR)EBO}$	Emitter-Base breakdown voltage	I_E = 100µA	7	-	V
$V_{CE(SAT)1}$	Collector-Emitter saturation voltage, Note 1	I_C = 150mA, I_B = 15mA	-	0.2	V
$V_{CE(SAT)2}$	Collector-Emitter saturation voltage, Note 1	I_C = 500mA, I_B = 50mA	-	0.5	V
$V_{BE(SAT)}$	Base-Emitter saturation voltage, Note 1	I_C = 150mA, I_B = 15mA	-	1.1	V
H_{FE1}	DC current gain, Note 1	I_C = 1mA, V_{CE} = 10V	90	-	-
H_{FE2}	DC current gain, Note 1	I_C = 10mA, V_{CE} = 10V	90	-	-
H_{FE3}	DC current gain, Note 1	I_C = 150mA, V_{CE} = 10V	100	300	-
F_T	Gain Bandwidth Product	V_{CE} = 10V, I_C = 50mA	100	-	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 SOC3700SW Low Power NPN Bipolar 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+11p/cm².	

Table 2 : Summary of failed parameters

6 Test Results

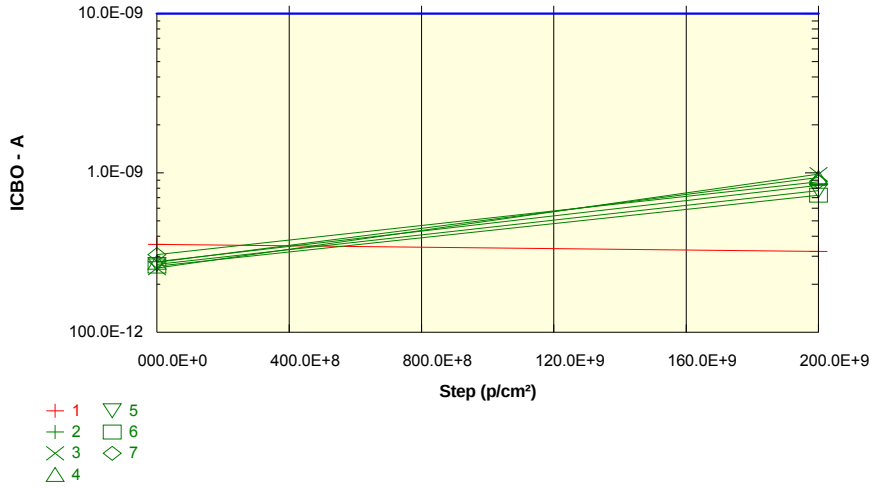
Test results including tables and graphics are provided in this section for each measured parameter.

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 = 90V
Unit : A
Spec Limit Max : 10.0E-09
Spec limits are represented in bold lines on the graphic.



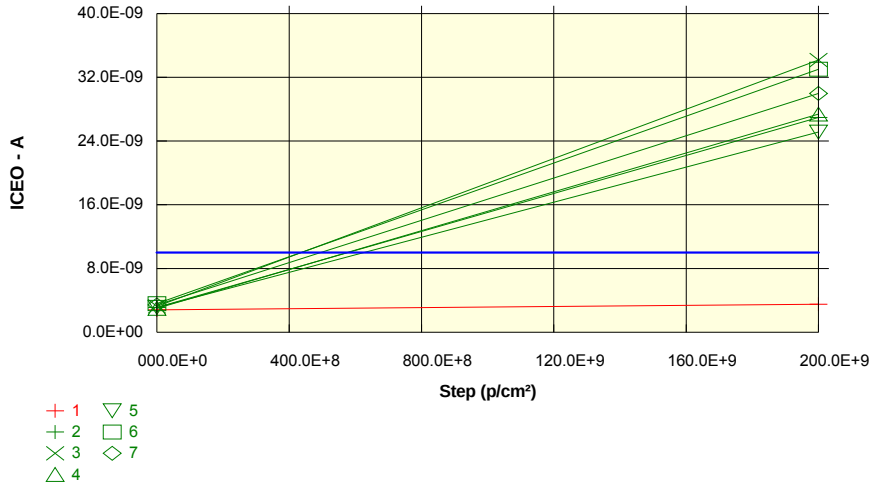
Measurements

ICBO	0 p/cm²	2E+11 p/cm²
1_REF	356.4E-12	321.0E-12
OFF samples		
2	277.2E-12	834.8E-12
3	252.6E-12	982.0E-12
4	274.8E-12	935.0E-12
5	266.2E-12	774.0E-12
6	260.3E-12	724.0E-12
7	307.4E-12	878.8E-12
Statistics		
Min	252.6E-12	724.0E-12
Max	307.4E-12	982.0E-12
Average	273.1E-12	854.8E-12
Sigma	17.4E-12	88.7E-12

Drift Calculation

ICBO	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	557.60E-12
3	-	729.40E-12
4	-	660.20E-12
5	-	507.80E-12
6	-	463.66E-12
7	-	571.40E-12
Average	-	581.68E-12
Sigma	-	89.50E-12

Test conditions : PROTONS
Parameter : Collector-Emitter cut-off current : ICEO
Vce = 80V
Unit : A
Spec Limit Max : 10.0E-09
Spec limits are represented in bold lines on the graphic.



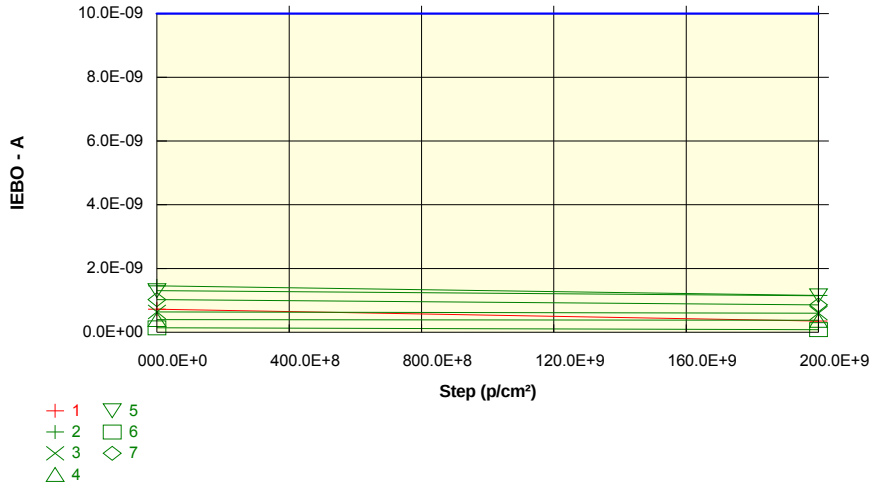
Measurements

ICEO	0 p/cm²	2E+11 p/cm²
1_REF	2.8E-09	3.5E-09
OFF samples		
2	3.1E-09	27.0E-09
3	3.2E-09	34.2E-09
4	3.0E-09	27.4E-09
5	3.1E-09	25.1E-09
6	3.6E-09	33.0E-09
7	3.4E-09	30.0E-09
Statistics		
Min	3.0E-09	25.1E-09
Max	3.6E-09	34.2E-09
Average	3.2E-09	29.4E-09
Sigma	205.3E-12	3.3E-09

Drift Calculation

ICEO	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	23.85E-09
3	-	30.91E-09
4	-	24.39E-09
5	-	22.00E-09
6	-	29.42E-09
7	-	26.56E-09
Average	-	26.19E-09
Sigma	-	3.14E-09

Test conditions : PROTONS
Parameter : Emitter-Base cut-off current : IEBO
Veb = 5V
Unit : A
Spec Limit Max : 10.0E-09
Spec limits are represented in bold lines on the graphic.



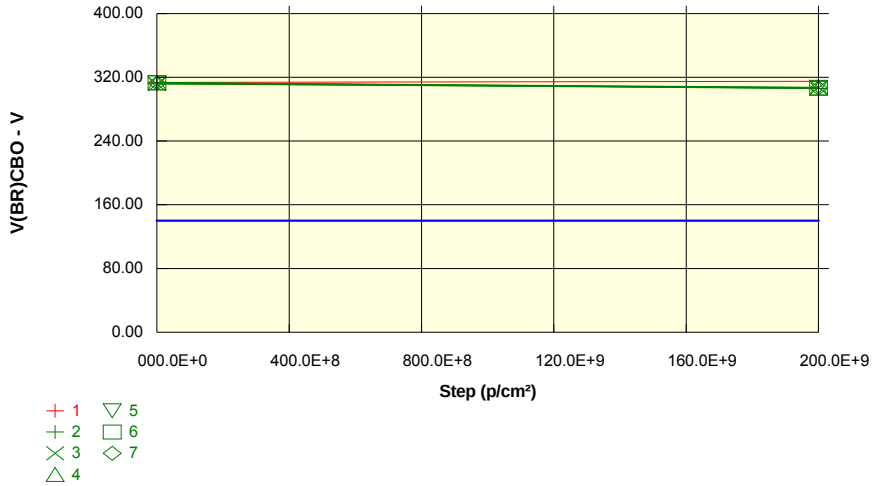
Measurements

IEBO	0 p/cm²	2E+11 p/cm²
1_REF	721.8E-12	352.0E-12
OFF samples		
2	1.5E-09	1.2E-09
3	635.4E-12	597.2E-12
4	397.4E-12	372.8E-12
5	1.3E-09	1.1E-09
6	140.6E-12	78.6E-12
7	1.0E-09	854.6E-12
Statistics		
Min	140.6E-12	78.6E-12
Max	1.5E-09	1.2E-09
Average	825.8E-12	700.1E-12
Sigma	474.5E-12	393.7E-12

Drift Calculation

IEBO	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	-298.20E-12
3	-	-38.20E-12
4	-	-24.60E-12
5	-	-162.20E-12
6	-	-61.98E-12
7	-	-169.20E-12
Average	-	-125.73E-12
Sigma	-	95.67E-12

Test conditions : PROTONS
Parameter : Collector-Base breakdown voltage : V(BR)CBO
Ic = 100µA
Unit : V
Spec Limit Min : 140.00
Spec limits are represented in bold lines on the graphic.



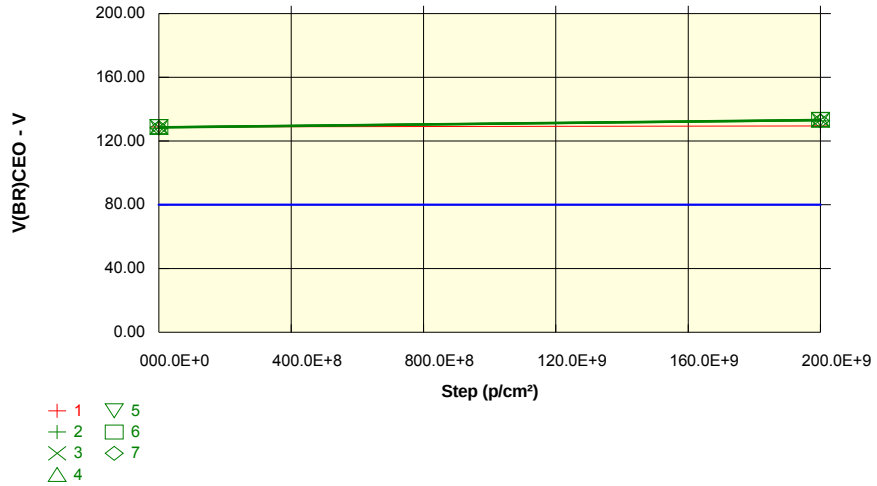
Measurements

V(BR)CBO	0 p/cm²	2E+11 p/cm²
1_REF	313.51	314.88
OFF samples		
2	312.09	306.07
3	311.48	307.09
4	313.24	306.33
5	313.30	307.38
6	313.15	306.79
7	312.76	306.50
Statistics		
Min	311.48	306.07
Max	313.30	307.38
Average	312.67	306.69
Sigma	0.67	0.45

Drift Calculation

V(BR)CBO	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	-6.02E+00
3	-	-4.39E+00
4	-	-6.91E+00
5	-	-5.92E+00
6	-	-6.36E+00
7	-	-6.26E+00
Average	-	-5.98E+00
Sigma	-	776.84E-03

Test conditions : PROTONS
Parameter : Collector-Emitter Breakdown voltage : V(BR)CEO
Ic = 30mA
Unit : V
Spec Limit Min : 80.00
Spec limits are represented in bold lines on the graphic.



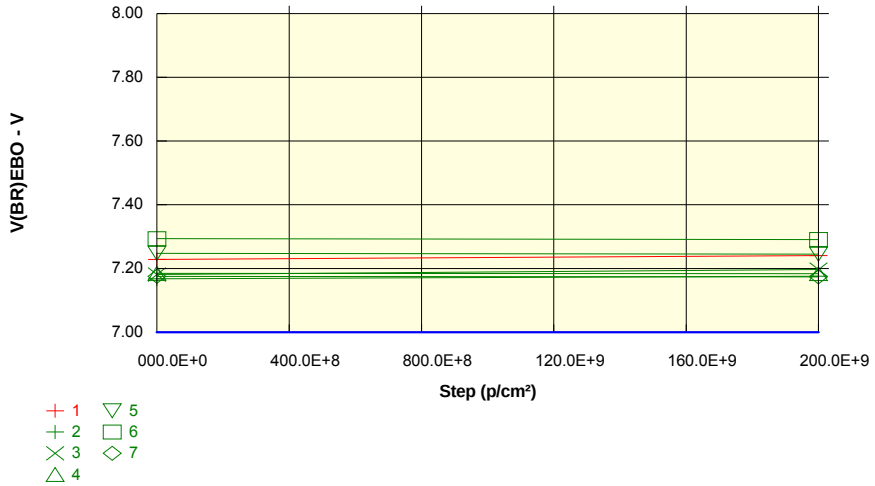
Measurements

V(BR)CEO	0 p/cm²	2E+11 p/cm²
1_REF	128.84	129.42
OFF samples		
2	128.05	132.64
3	128.82	133.30
4	128.54	133.01
5	129.08	133.66
6	128.96	133.46
7	128.28	132.61
Statistics		
Min	128.05	132.61
Max	129.08	133.66
Average	128.62	133.11
Sigma	0.37	0.40

Drift Calculation

V(BR)CEO	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	4.59E+00
3	-	4.48E+00
4	-	4.47E+00
5	-	4.57E+00
6	-	4.50E+00
7	-	4.34E+00
Average	-	4.49E+00
Sigma	-	82.14E-03

Test conditions : PROTONS
Parameter : Emitter-Base breakdown voltage : V(BR)EBO
Ie = 100µA
Unit : V
Spec Limit Min : 7.00
Spec limits are represented in bold lines on the graphic.



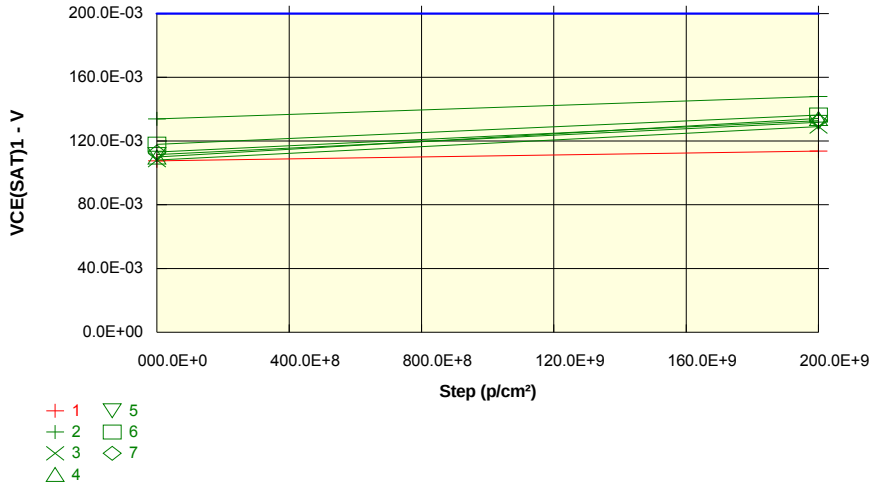
Measurements

V(BR)EBO	0 p/cm²	2E+11 p/cm²
1_REF	7.23	7.24
OFF samples		
2	7.17	7.18
3	7.18	7.20
4	7.18	7.18
5	7.25	7.24
6	7.29	7.29
7	7.18	7.17
Statistics		
Min	7.17	7.17
Max	7.29	7.29
Average	7.21	7.21
Sigma	0.05	0.04

Drift Calculation

V(BR)EBO	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	8.40E-03
3	-	15.60E-03
4	-	-800.13E-06
5	-	-2.80E-03
6	-	-3.00E-03
7	-	-1.60E-03
Average	-	2.63E-03
Sigma	-	6.98E-03

Test conditions : PROTONS
Parameter : Collector-Emitter saturation voltage : VCE(SAT)1
Ic = 150mA ; Ib = 15mA
Unit : V
Spec Limit Max : 200.0E-03
Spec limits are represented in bold lines on the graphic.



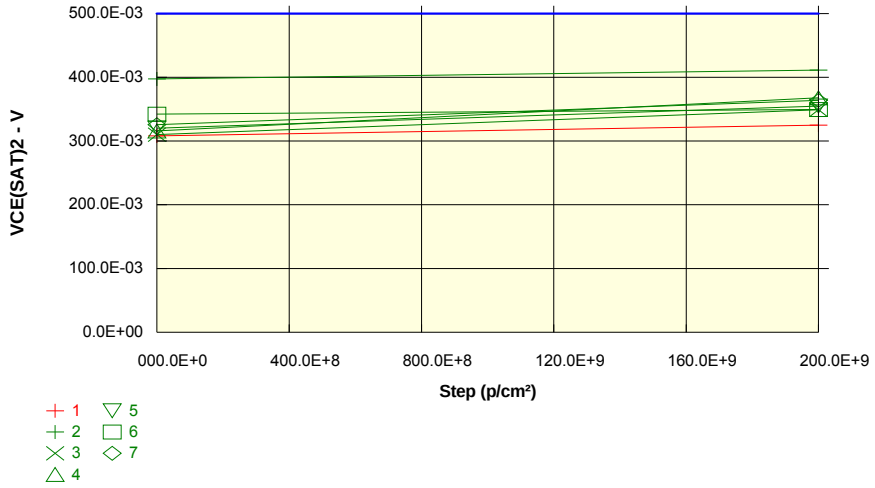
Measurements

VCE(SAT)1	0 p/cm²	2E+11 p/cm²
1_REF	107.6E-03	113.6E-03
OFF samples		
2	133.9E-03	147.9E-03
3	108.0E-03	129.1E-03
4	110.0E-03	134.2E-03
5	111.5E-03	131.7E-03
6	118.0E-03	136.3E-03
7	113.1E-03	132.7E-03
Statistics		
Min	108.0E-03	129.1E-03
Max	133.9E-03	147.9E-03
Average	115.7E-03	135.3E-03
Sigma	8.7E-03	6.1E-03

Drift Calculation

VCE(SAT)1	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	14.00E-03
3	-	21.04E-03
4	-	24.24E-03
5	-	20.20E-03
6	-	18.28E-03
7	-	19.64E-03
Average	-	19.57E-03
Sigma	-	3.08E-03

Test conditions : PROTONS
Parameter : Collector-Emitter saturation voltage : VCE(SAT)2
Ic = 500mA ; Ib = 50mA
Unit : V
Spec Limit Max : 500.0E-03
Spec limits are represented in bold lines on the graphic.



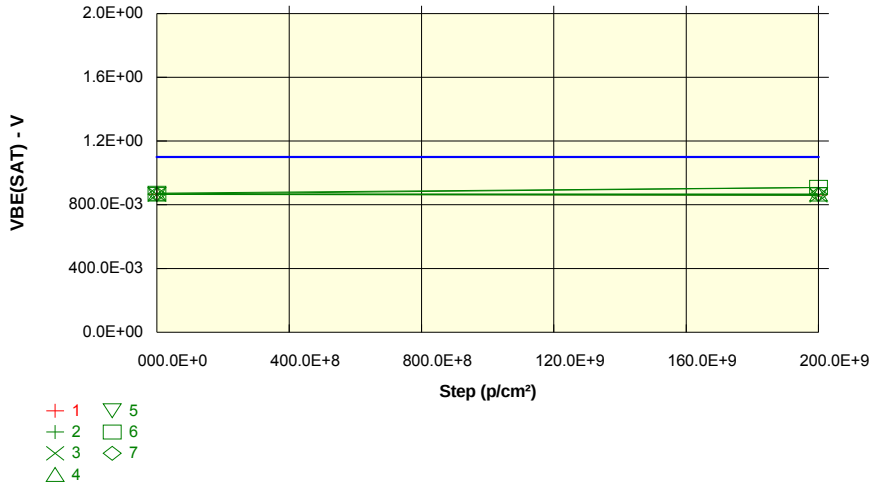
Measurements

VCE(SAT)2	0 p/cm²	2E+11 p/cm²
1_REF	308.2E-03	324.9E-03
OFF samples		
2	397.4E-03	411.4E-03
3	310.0E-03	349.1E-03
4	315.9E-03	367.8E-03
5	320.1E-03	354.9E-03
6	342.4E-03	349.5E-03
7	325.7E-03	363.9E-03
Statistics		
Min	310.0E-03	349.1E-03
Max	397.4E-03	411.4E-03
Average	335.3E-03	366.1E-03
Sigma	29.6E-03	21.4E-03

Drift Calculation

VCE(SAT)2	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	13.92E-03
3	-	39.08E-03
4	-	51.84E-03
5	-	34.80E-03
6	-	7.12E-03
7	-	38.16E-03
Average	-	30.82E-03
Sigma	-	15.42E-03

Test conditions : PROTONS
Parameter : Base-Emitter saturation voltage : VBE(SAT)
Ic = 150mA ; Ib = 15mA
Unit : V
Spec Limit Max : 1.1E+00
Spec limits are represented in bold lines on the graphic.



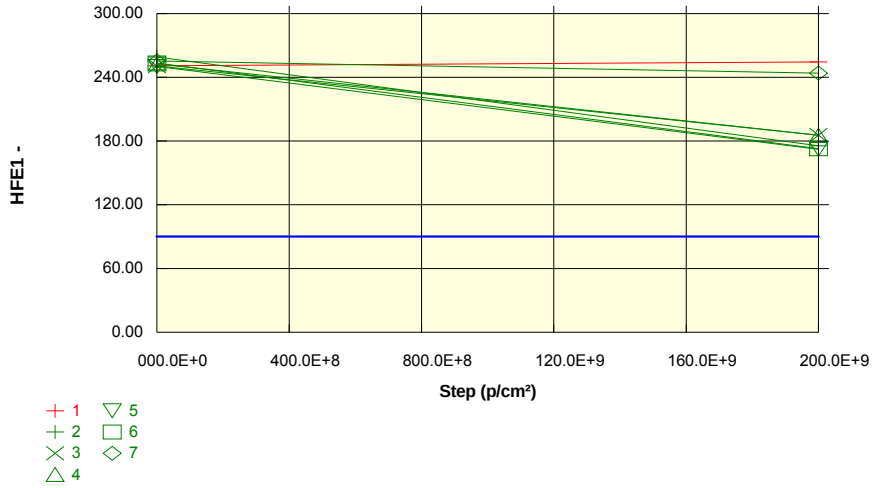
Measurements

VBE(SAT)	0 p/cm²	2E+11 p/cm²
1_REF	865.7E-03	862.1E-03
OFF samples		
2	866.3E-03	908.4E-03
3	865.0E-03	858.3E-03
4	866.7E-03	867.1E-03
5	864.8E-03	862.8E-03
6	872.5E-03	909.6E-03
7	866.6E-03	865.2E-03
Statistics		
Min	864.8E-03	858.3E-03
Max	872.5E-03	909.6E-03
Average	867.0E-03	878.5E-03
Sigma	2.6E-03	21.7E-03

Drift Calculation

VBE(SAT)	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	42.04E-03
3	-	-6.72E-03
4	-	440.00E-06
5	-	-2.00E-03
6	-	37.04E-03
7	-	-1.44E-03
Average	-	11.56E-03
Sigma	-	19.95E-03

Test conditions : PROTONS
Parameter : DC current gain : HFE1
Ic = 1mA ; Vce = 10V
Unit :
Spec Limit Min : 90.00
Spec limits are represented in bold lines on the graphic.



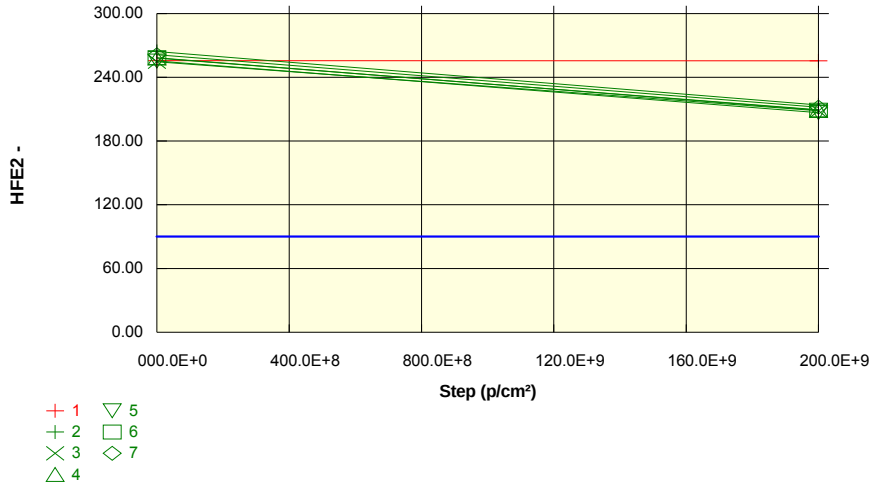
Measurements

HFE1	0 p/cm²	2E+11 p/cm²
1_REF	250.83	254.47
OFF samples		
2	259.21	175.47
3	250.73	185.58
4	252.56	185.58
5	250.24	172.23
6	253.53	172.71
7	255.39	243.92
Statistics		
Min	250.24	172.23
Max	259.21	243.92
Average	253.61	189.25
Sigma	3.04	25.06

Drift Calculation

HFE1	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	1.84E-03
3	-	1.40E-03
4	-	1.43E-03
5	-	1.81E-03
6	-	1.85E-03
7	-	184.11E-06
Average	-	1.42E-03
Sigma	-	582.89E-06

Test conditions : PROTONS
Parameter : DC current gain : HFE2
Ic = 10mA ; Vce = 10V
Unit :
Spec Limit Min : 90.00
Spec limits are represented in bold lines on the graphic.



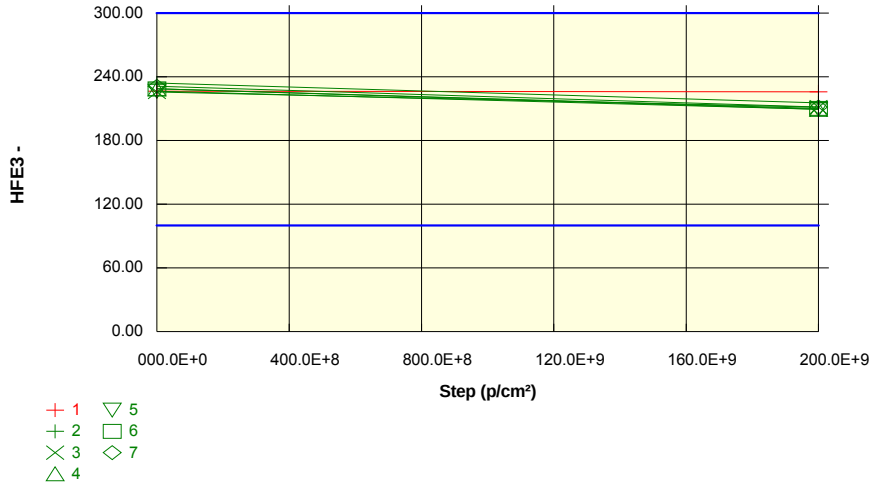
Measurements

HFE2	0 p/cm²	2E+11 p/cm²
1_REF	255.65	255.48
OFF samples		
2	264.34	213.95
3	254.65	208.53
4	258.14	209.43
5	255.43	206.73
6	258.45	208.90
7	261.28	211.86
Statistics		
Min	254.65	206.73
Max	264.34	213.95
Average	258.72	209.90
Sigma	3.31	2.36

Drift Calculation

HFE2	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	890.86E-06
3	-	868.38E-06
4	-	901.13E-06
5	-	922.39E-06
6	-	917.74E-06
7	-	892.67E-06
Average	-	898.86E-06
Sigma	-	18.01E-06

Test conditions : PROTONS
Parameter : DC current gain : HFE3
Ic = 150mA ; Vce = 10V
Unit :
Spec Limit Min : 100.00
Spec Limit Max : 300.00
Spec limits are represented in bold lines on the graphic.



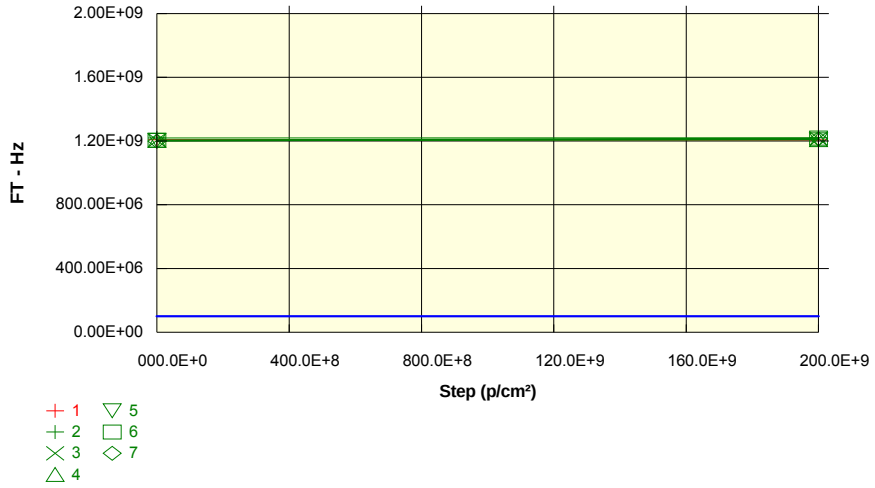
Measurements

HFE3	0 p/cm²	2E+11 p/cm²
1_REF	226.43	225.86
OFF samples		
2	234.18	215.33
3	225.76	211.39
4	228.67	209.32
5	226.46	209.25
6	228.62	210.24
7	231.02	211.52
Statistics		
Min	225.76	209.25
Max	234.18	215.33
Average	229.12	211.18
Sigma	2.83	2.06

Drift Calculation

HFE3	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	373.81E-06
3	-	301.05E-06
4	-	404.20E-06
5	-	363.03E-06
6	-	382.43E-06
7	-	399.04E-06
Average	-	370.59E-06
Sigma	-	34.11E-06

Test conditions : PROTONS
Parameter : Gain bandwidth product : FT
Vce = 10V ; Ic = 50mA
Unit : Hz
Spec Limit Min : 100.00E+06
Spec limits are represented in bold lines on the graphic.



Measurements

FT	0 p/cm²	2E+11 p/cm²
1_REF	1.21E+09	1.21E+09
OFF samples		
2	1.22E+09	1.22E+09
3	1.21E+09	1.21E+09
4	1.20E+09	1.21E+09
5	1.20E+09	1.21E+09
6	1.21E+09	1.22E+09
7	1.20E+09	1.21E+09
Statistics		
Min	1.20E+09	1.21E+09
Max	1.22E+09	1.22E+09
Average	1.21E+09	1.21E+09
Sigma	6.43E+06	4.41E+06

Drift Calculation

FT	0 p/cm²	2E+11 p/cm²
OFF samples		
2	-	1.97E+06
3	-	9.75E+06
4	-	6.67E+06
5	-	5.28E+06
6	-	12.55E+06
7	-	16.12E+06
Average	-	8.72E+06
Sigma	-	4.69E+06