PROTONS TEST REPORT

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

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

Part Type : OLS449

Package : SMD

Description : Optocoupler with Radiation Tolerant Phototransistor

Manufacturer: Isolink Inc.

Date Code: 0949

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/0882	Issue : 01	Date :	June 7th, 2011
Written by :	G. FAUCHON	Technician		
Approved by :	O.PERROTIN	Study Manager		
Authorized by:	J.F. PASCAL	Technical Manager		

CHANGE RECORD

ISSUE	DATE	PAGE	DESCRIPTION OF CHANGES
01	06/07/2011	All	Original Issue

PROTONS TEST REPORT
on
OLS449
Optocoupler with Radiation Tolerant Phototransistor

From Isolink Inc.

TABLE OF CONTENTS

1 Introduction

In the scope of the ESA study: “Survey of Critical Components for 150 kRad Power Systems”, a protons test of the Isolink Inc. OLS449, Optocoupler with Radiation Tolerant Phototransistor 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/0239 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 provided.

2 Applicable and Reference Documents

2.1 Applicable Documents

- Hirex Engineering Radiation Test Plan: HRX/SPE/0239 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.

2.2 Reference Documents

- Isolink Inc. datasheet

3 Test Samples

7 samples of the OLS449 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 Numbers	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 OLS449 is given below:

Part Number: OLS449

Top Marking: S OLS449 0949

Bottom Marking: -

Date Code: 0949

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.

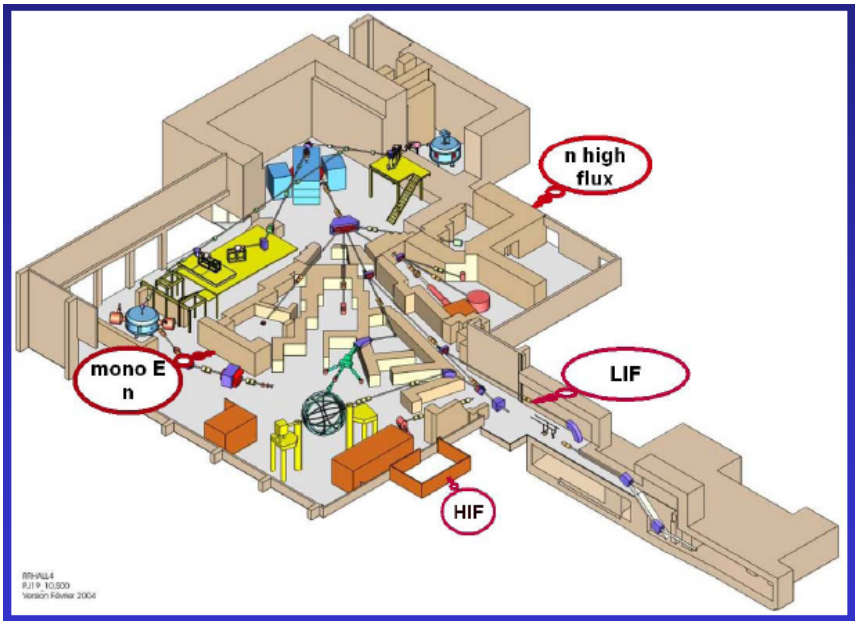


Figure 1 : LIF layout and typical experimental set-up

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

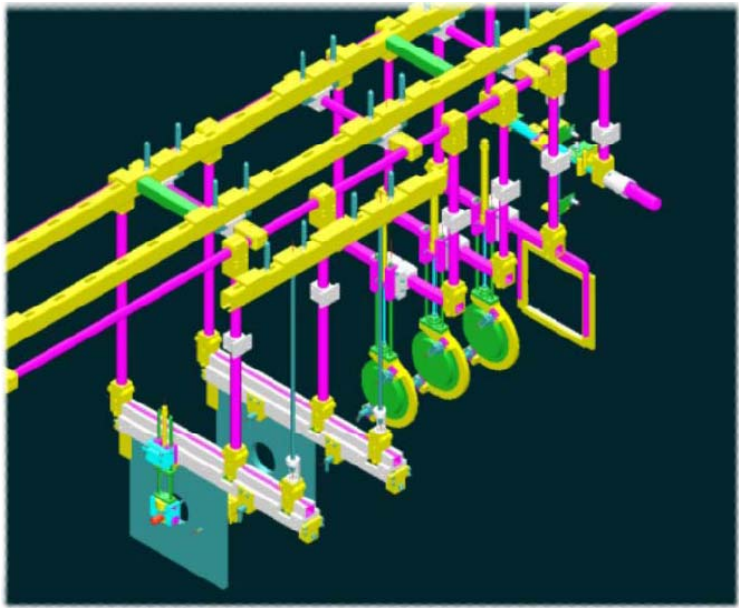


Figure 2: LIF Energy degraders

The irradiation conditions used for this test are provided in the following tables:

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 OLS449 is provided in Figure 3.

A HP4142 DC tester was used to perform required measurements.

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

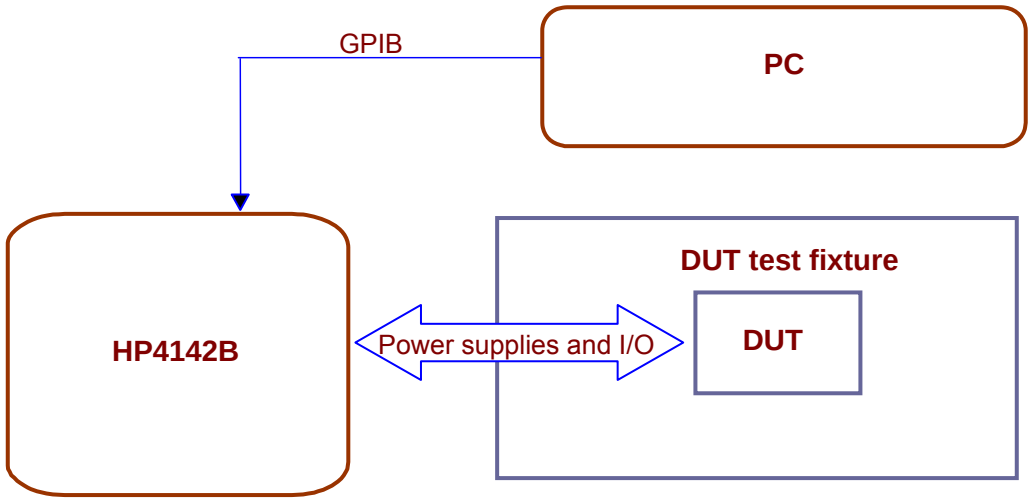


Figure 3 : OLS449 test program principle

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

Parameters	Description	Conditions	Spec		Unit
			Min	Max	
IC(ON)	On-State Collector Current	IF = 1mA ; VCE = 5V	15	40	mA
			7	-	mA
			7	-	mA
ICB(ON)	On-State Collector-Base Current	IF = 10mA; VCB = 5V	300	-	µA
VCE(SAT)	Saturation Voltage	IF = 1mA ; IC = 5mA	-	0.3	V
BVCEO	Breakdown Voltage Collector to Emitter	I CE = 1 mA	65	-	V
BVCBO	Breakdown Voltage Collector to Base	I CB = 100 µA	65	-	V
BVEBO	Breakdown Voltage Emitter to Base	I EB = 100 µA	7	-	V
ICE(OFF)	Off-State Leakage Current Collector to Emitter	VCE = 5V	-	-	nA
			-	-	µA
ICE(OFF)	Off-State Leakage Current Collector to Emitter	VCE = 20V	-	100	nA
			-	100	µA
ICE(OFF)	Off-State Leakage Current Collector to Emitter	VCE = 40V	-	-	nA
			-	-	µA
ICB(OFF)	Off-State Leakage Current Collector to Base	VCB = 20V	-	10	nA
VF	Input Forward Voltage	IF = 10mA	1.2	1.7	V
			1.3	1.9	V
			1.1	1.6	V
IR	Input Reverse Current	VR = 2V	-	100	µA
CTR	Current Transfert Ratio	IF = 1mA ; VCE = 5V	-	-	
		IF = 10mA ; VCE = 5V			
		IF = 1mA ; VCE = 40V			
		IF = 10mA ; VCE = 40V			

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 Isolink Inc. OLS449 Optocoupler with Radiation Tolerant Phototransistor in SMD 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 the 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
IC(ON)	0 & 2E+11 kRad(Si)	
VCE(SAT)	0 & 2E+11 kRad(Si)	

Table 2 : Summary of failed parameters

6 Test Results

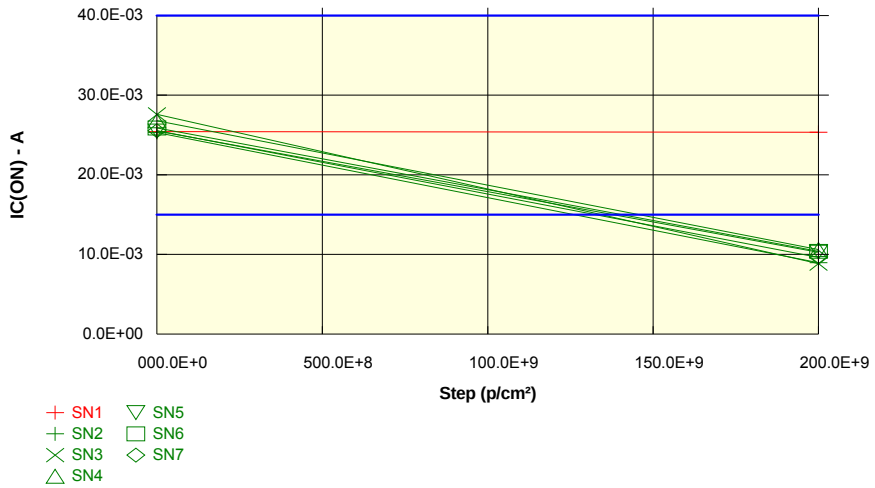
Test results including tables and graphics are provided in this section for each measured parameter.

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 : On-State Collector Current : IC(ON)
IF = 1mA ; VCE = 5V
Unit : A
Spec Limit Min : 15.0E-03
Spec Limit Max : 40.0E-03
Spec limits are represented in bold lines on the graphic.



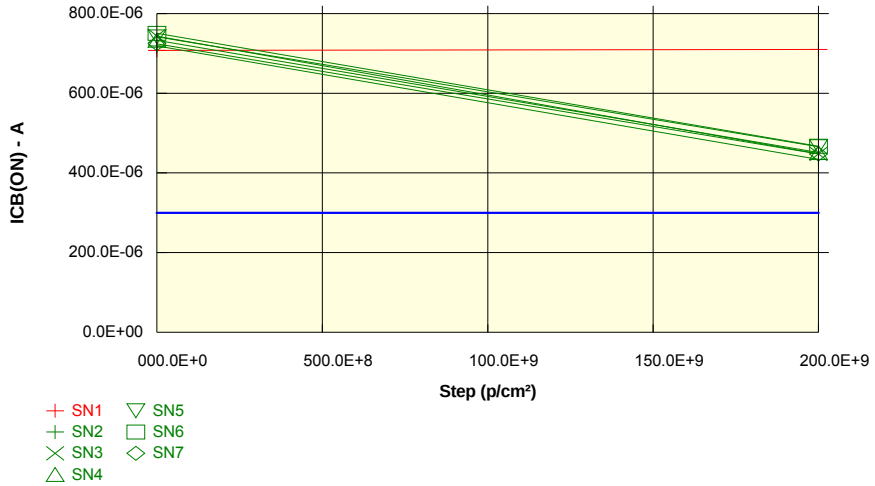
Measurements

IC(ON)	0 p/cm²	2E+11 p/cm²
SN1_REF	25.4E-03	25.3E-03
OFF samples		
SN2	25.3E-03	9.0E-03
SN3	27.6E-03	8.9E-03
SN4	26.8E-03	10.6E-03
SN5	25.5E-03	10.3E-03
SN6	25.9E-03	10.4E-03
SN7	25.5E-03	9.6E-03
Statistics		
Min	25.3E-03	8.9E-03
Max	27.6E-03	10.6E-03
Average	26.1E-03	9.8E-03
Sigma	817.1E-06	692.9E-06

Drift Calculation

IC(ON)	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-16.35E-03
SN3	-	-18.73E-03
SN4	-	-16.16E-03
SN5	-	-15.21E-03
SN6	-	-15.50E-03
SN7	-	-15.90E-03
Average	-	-16.31E-03
Sigma	-	1.15E-03

Test conditions : Protons
Parameter : On-State Collector-Base Current : ICB(ON)
IF = 10mA; VCB = 5V
Unit : A
Spec Limit Min : 300.0E-06
Spec limits are represented in bold lines on the graphic.



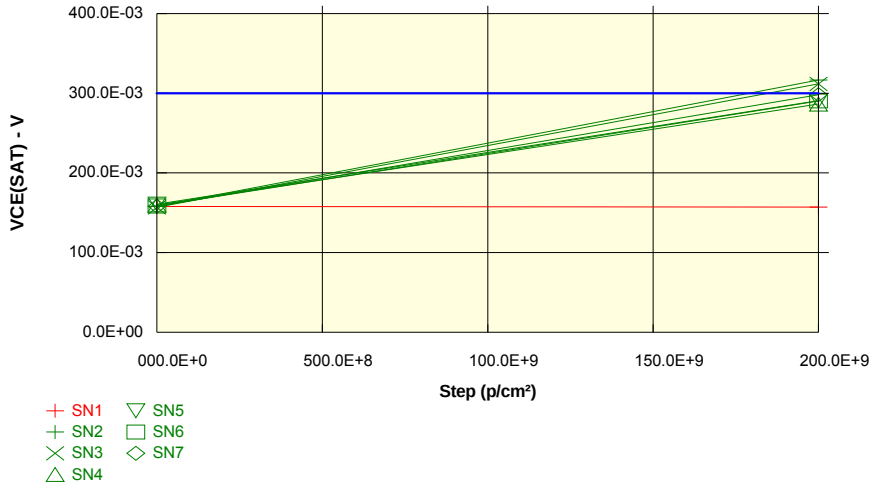
Measurements

ICB(ON)	0 p/cm²	2E+11 p/cm²
SN1_REF	707.7E-06	710.0E-06
OFF samples		
SN2	718.6E-06	433.9E-06
SN3	743.7E-06	448.0E-06
SN4	733.0E-06	451.1E-06
SN5	741.7E-06	465.8E-06
SN6	750.4E-06	466.9E-06
SN7	724.2E-06	447.5E-06
Statistics		
Min	718.6E-06	433.9E-06
Max	750.4E-06	466.9E-06
Average	735.3E-06	452.2E-06
Sigma	11.2E-06	11.4E-06

Drift Calculation

ICB(ON)	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-284.64E-06
SN3	-	-295.78E-06
SN4	-	-281.88E-06
SN5	-	-275.92E-06
SN6	-	-283.46E-06
SN7	-	-276.74E-06
Average	-	-283.07E-06
Sigma	-	6.54E-06

Test conditions : Protons
Parameter : Saturation Voltage : VCE(SAT)
IF = 1mA ; IC = 5mA
Unit : V
Spec Limit Max : 300.0E-03
Spec limits are represented in bold lines on the graphic.



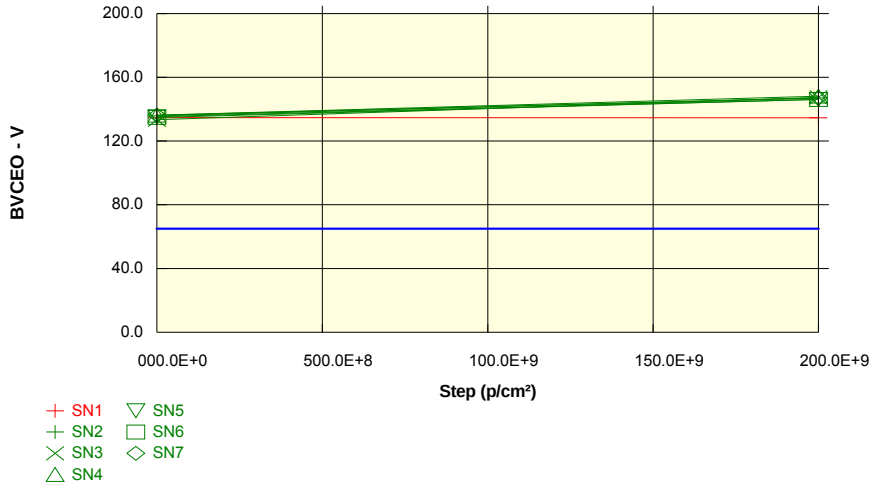
Measurements

VCE(SAT)	0 p/cm²	2E+11 p/cm²
SN1_REF	158.0E-03	157.0E-03
OFF samples		
SN2	158.1E-03	316.5E-03
SN3	156.8E-03	311.8E-03
SN4	159.8E-03	286.4E-03
SN5	160.8E-03	290.6E-03
SN6	158.5E-03	290.4E-03
SN7	158.3E-03	298.2E-03
Statistics		
Min	156.8E-03	286.4E-03
Max	160.8E-03	316.5E-03
Average	158.7E-03	299.0E-03
Sigma	1.3E-03	11.4E-03

Drift Calculation

VCE(SAT)	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	158.40E-03
SN3	-	155.08E-03
SN4	-	126.64E-03
SN5	-	129.76E-03
SN6	-	131.84E-03
SN7	-	139.96E-03
Average	-	140.28E-03
Sigma	-	12.35E-03

Test conditions : Protons
Parameter : Breakdown Voltage Collector To Emitter : BVCEO
I CE = 1 mA
Unit : V
Spec Limit Min : 65.0
Spec limits are represented in bold lines on the graphic.



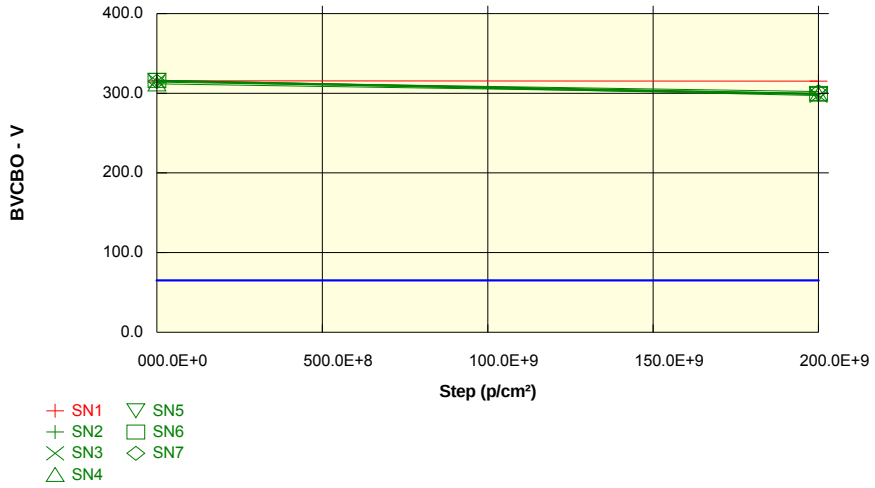
Measurements

BVCEO	0 p/cm²	2E+11 p/cm²
SN1_REF	134.7	134.6
OFF samples		
SN2	135.7	147.1
SN3	133.4	147.4
SN4	136.2	148.2
SN5	135.2	146.1
SN6	134.9	146.1
SN7	136.3	147.0
Statistics		
Min	133.4	146.1
Max	136.3	148.2
Average	135.3	147.0
Sigma	1.0	0.7

Drift Calculation

BVCEO	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	11.34E+00
SN3	-	14.02E+00
SN4	-	12.00E+00
SN5	-	10.82E+00
SN6	-	11.24E+00
SN7	-	10.76E+00
Average	-	11.70E+00
Sigma	-	1.12E+00

Test conditions : Protons
Parameter : Breakdown Voltage Collector To Base : BVCBO
I CB = 100 µA
Unit : V
Spec Limit Min : 65.0
Spec limits are represented in bold lines on the graphic.



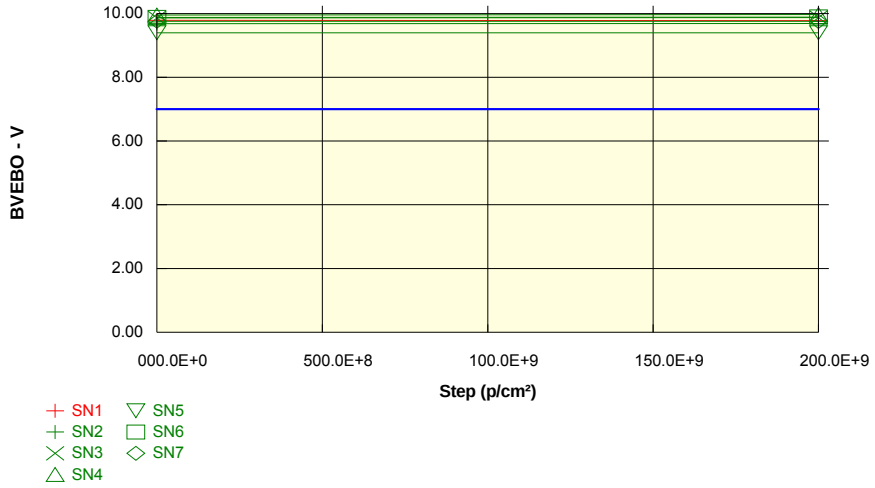
Measurements

BVCBO	0 p/cm²	2E+11 p/cm²
SN1_REF	315.7	315.1
OFF samples		
SN2	314.0	299.7
SN3	315.2	297.2
SN4	311.9	298.8
SN5	316.4	298.5
SN6	316.1	299.9
SN7	314.9	302.0
Statistics		
Min	311.9	297.2
Max	316.4	302.0
Average	314.8	299.3
Sigma	1.5	1.5

Drift Calculation

BVCBO	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-14.28E+00
SN3	-	-18.07E+00
SN4	-	-13.07E+00
SN5	-	-17.90E+00
SN6	-	-16.25E+00
SN7	-	-12.94E+00
Average	-	-15.42E+00
Sigma	-	2.12E+00

Test conditions : Protons
Parameter : Breakdown Voltage Emitter To Base : BVEBO
I EB = 100 µA
Unit : V
Spec Limit Min : 7.00
Spec limits are represented in bold lines on the graphic.



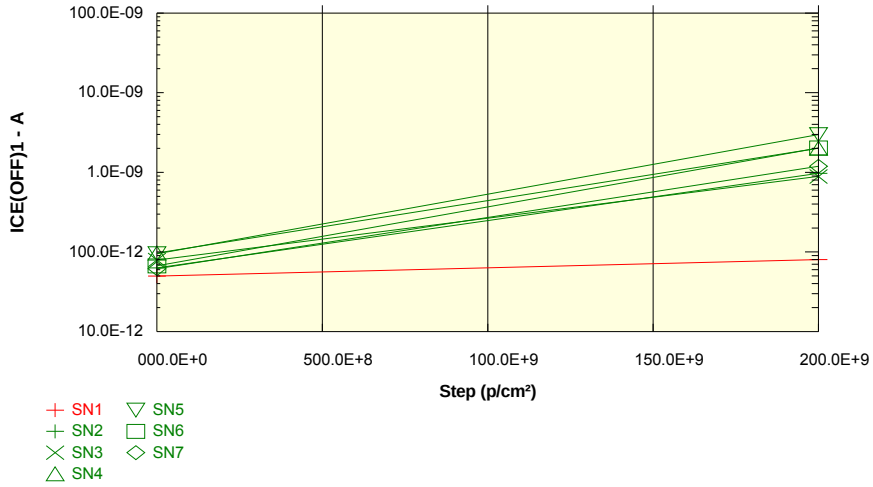
Measurements

BVEBO	0 p/cm²	2E+11 p/cm²
SN1_REF	9.79	9.77
OFF samples		
SN2	9.69	9.69
SN3	9.86	9.87
SN4	9.95	9.97
SN5	9.40	9.40
SN6	9.88	9.89
SN7	9.76	9.76
Statistics		
Min	9.40	9.40
Max	9.95	9.97
Average	9.76	9.76
Sigma	0.18	0.19

Drift Calculation

BVEBO	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	800.13E-06
SN3	-	9.20E-03
SN4	-	17.20E-03
SN5	-	400.54E-06
SN6	-	12.40E-03
SN7	-	-3.60E-03
Average	-	6.07E-03
Sigma	-	7.38E-03

Test conditions : Protons
Parameter : Off-State Leakage Current Collector To Emitter : ICE(OFF)1
VCE=5V
Unit : A
No spec limit specified.



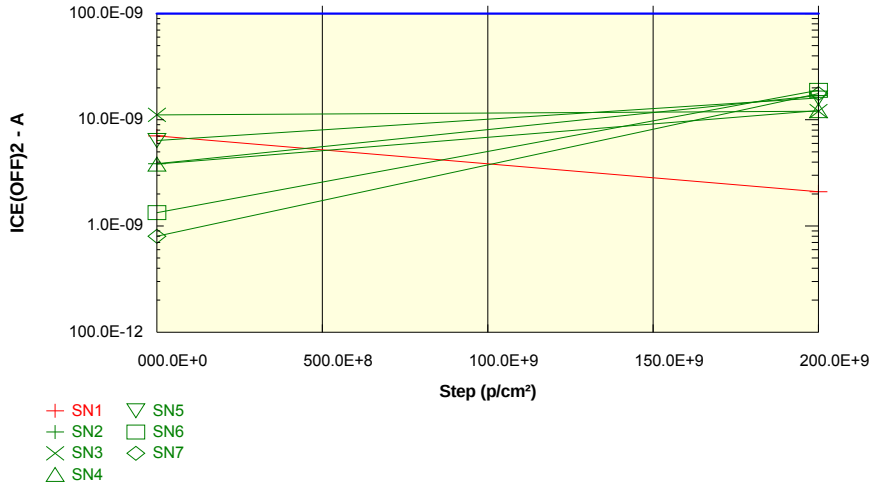
Measurements

ICE(OFF)1	0 p/cm²	2E+11 p/cm²
SN1_REF	49.9E-12	80.0E-12
OFF samples		
SN2	63.1E-12	972.8E-12
SN3	79.4E-12	888.2E-12
SN4	96.7E-12	2.0E-09
SN5	95.0E-12	3.0E-09
SN6	66.9E-12	2.0E-09
SN7	61.9E-12	1.2E-09
Statistics		
Min	61.9E-12	888.2E-12
Max	96.7E-12	3.0E-09
Average	77.2E-12	1.7E-09
Sigma	14.4E-12	736.8E-12

Drift Calculation

ICE(OFF)1	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	909.66E-12
SN3	-	808.80E-12
SN4	-	1.91E-09
SN5	-	2.88E-09
SN6	-	1.95E-09
SN7	-	1.13E-09
Average	-	1.60E-09
Sigma	-	727.50E-12

Test conditions : Protons
Parameter : Off-State Leakage Current Collector To Emitter : ICE(OFF)2
VCE=20V
Unit : A
Spec Limit Max : 100.0E-09
Spec limits are represented in bold lines on the graphic.



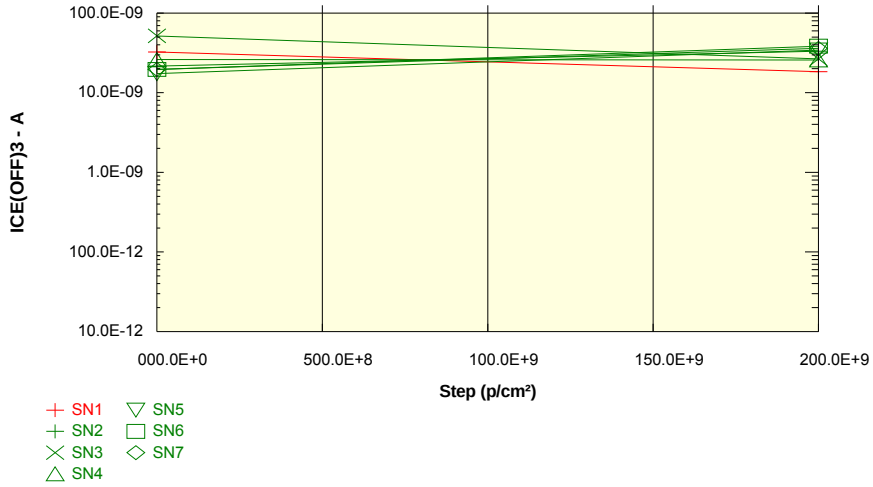
Measurements

ICE(OFF)2	0 p/cm²	2E+11 p/cm²
SN1_REF	7.0E-09	2.1E-09
OFF samples		
SN2	3.9E-09	16.9E-09
SN3	11.2E-09	12.1E-09
SN4	3.8E-09	12.2E-09
SN5	6.4E-09	16.1E-09
SN6	1.3E-09	19.0E-09
SN7	800.0E-12	17.7E-09
Statistics		
Min	800.0E-12	12.1E-09
Max	11.2E-09	19.0E-09
Average	4.6E-09	15.6E-09
Sigma	3.5E-09	2.6E-09

Drift Calculation

ICE(OFF)2	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	13.03E-09
SN3	-	910.00E-12
SN4	-	8.38E-09
SN5	-	9.69E-09
SN6	-	17.62E-09
SN7	-	16.86E-09
Average	-	11.08E-09
Sigma	-	5.67E-09

Test conditions : Protons
Parameter : Off-State Leakage Current Collector To Emitter : ICE(OFF)3
VCE=40V
Unit : A
No spec limit specified.



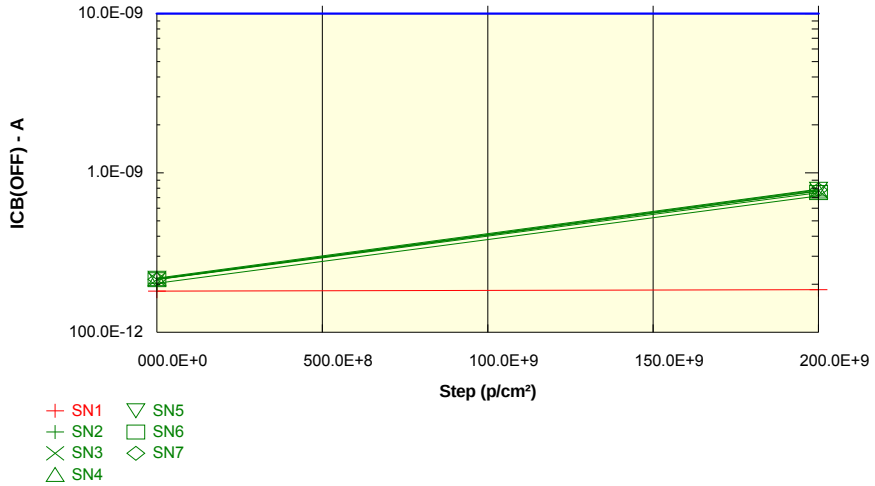
Measurements

ICE(OFF)3	0 p/cm²	2E+11 p/cm²
SN1_REF	32.4E-09	18.4E-09
OFF samples		
SN2	21.5E-09	33.2E-09
SN3	51.8E-09	26.7E-09
SN4	26.1E-09	25.8E-09
SN5	17.4E-09	34.3E-09
SN6	19.6E-09	38.5E-09
SN7	19.6E-09	36.1E-09
Statistics		
Min	17.4E-09	25.8E-09
Max	51.8E-09	38.5E-09
Average	26.0E-09	32.4E-09
Sigma	11.8E-09	4.7E-09

Drift Calculation

ICE(OFF)3	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	11.72E-09
SN3	-	-25.10E-09
SN4	-	-280.00E-12
SN5	-	16.96E-09
SN6	-	18.90E-09
SN7	-	16.44E-09
Average	-	6.44E-09
Sigma	-	15.46E-09

Test conditions : Protons
Parameter : Off-State Leakage Current Collector To Base : ICB(OFF)
VCB=20V
Unit : A
Spec Limit Max : 10.0E-09
Spec limits are represented in bold lines on the graphic.



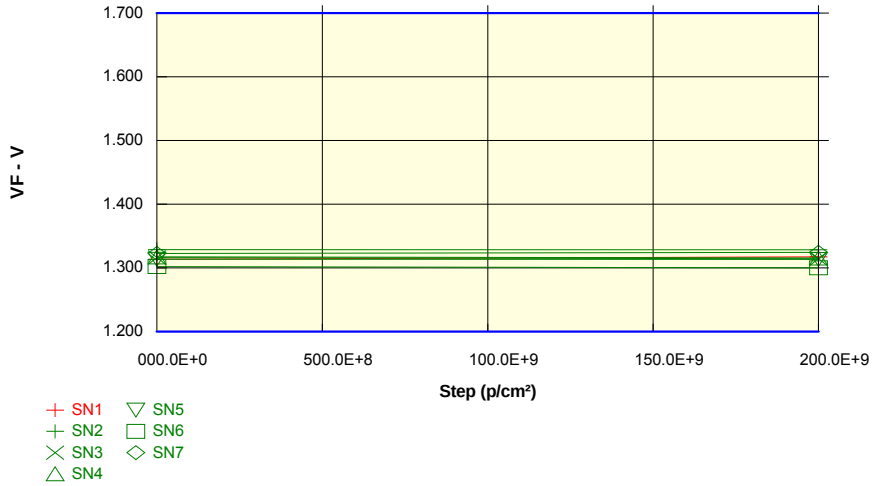
Measurements

ICB(OFF)	0 p/cm²	2E+11 p/cm²
SN1_REF	181.2E-12	184.8E-12
OFF samples		
SN2	202.9E-12	715.7E-12
SN3	214.2E-12	772.5E-12
SN4	216.9E-12	769.3E-12
SN5	218.6E-12	789.4E-12
SN6	214.0E-12	752.5E-12
SN7	214.8E-12	784.1E-12
Statistics		
Min	202.9E-12	715.7E-12
Max	218.6E-12	789.4E-12
Average	213.5E-12	763.9E-12
Sigma	5.0E-12	24.6E-12

Drift Calculation

ICB(OFF)	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	512.78E-12
SN3	-	558.28E-12
SN4	-	552.46E-12
SN5	-	570.86E-12
SN6	-	538.48E-12
SN7	-	569.38E-12
Average	-	550.37E-12
Sigma	-	20.01E-12

Test conditions : Protons
Parameter : Input Forward Voltage : VF
IF=10mA
Unit : V
Spec Limit Min : 1.200
Spec Limit Max : 1.700
Spec limits are represented in bold lines on the graphic.



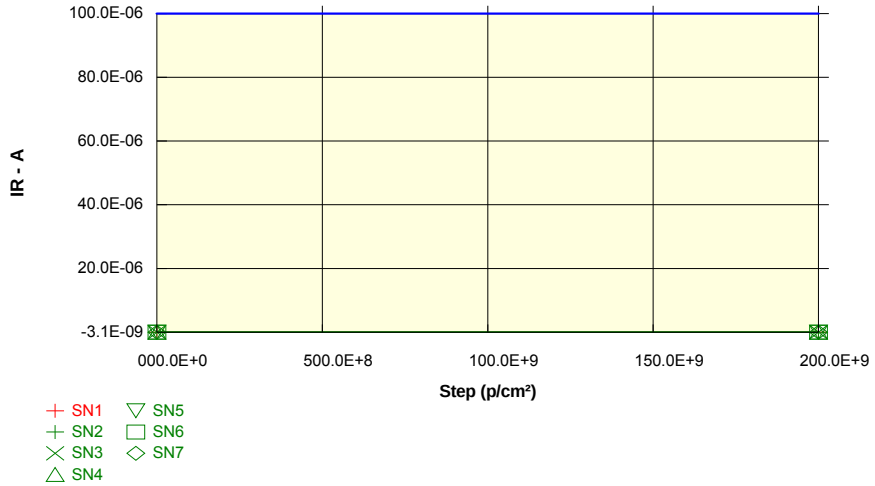
Measurements

VF	0 p/cm²	2E+11 p/cm²
SN1_REF	1.314	1.317
OFF samples		
SN2	1.329	1.328
SN3	1.316	1.314
SN4	1.317	1.316
SN5	1.314	1.313
SN6	1.302	1.300
SN7	1.323	1.324
Statistics		
Min	1.302	1.300
Max	1.329	1.328
Average	1.317	1.316
Sigma	0.008	0.009

Drift Calculation

VF	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	-399.95E-06
SN3	-	-1.60E-03
SN4	-	-1.60E-03
SN5	-	-399.95E-06
SN6	-	-2.00E-03
SN7	-	1.60E-03
Average	-	-733.34E-06
Sigma	-	1.21E-03

Test conditions : Protons
Parameter : Input Reverse Current : IR
VR=2V
Unit : A
Spec Limit Max : 100.0E-06
Spec limits are represented in bold lines on the graphic.



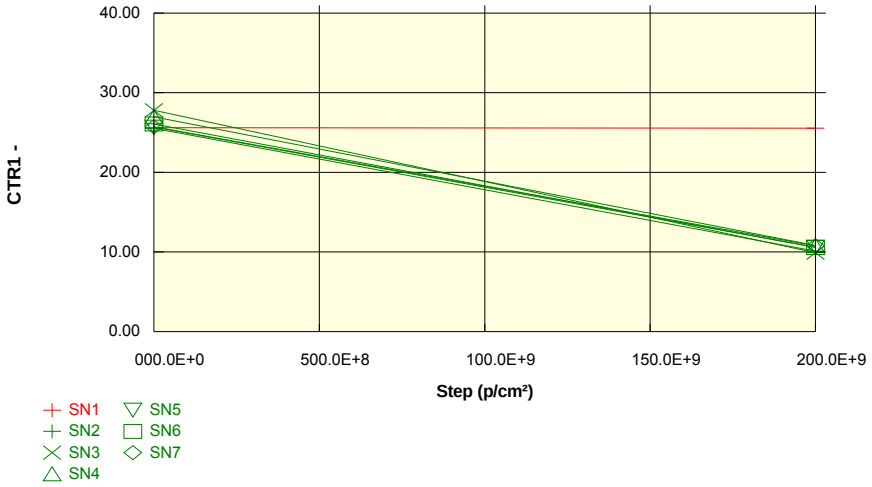
Measurements

IR	0 p/cm²	2E+11 p/cm²
SN1_REF	-15.7E-12	-14.9E-12
OFF samples		
SN2	-3.1E-09	-2.9E-09
SN3	-10.1E-12	-11.8E-12
SN4	-1.9E-09	-1.2E-09
SN5	-15.0E-12	-12.5E-12
SN6	-10.1E-12	-6.5E-12
SN7	-7.1E-12	-12.3E-12
Statistics		
Min	-3.1E-09	-2.9E-09
Max	-7.1E-12	-6.5E-12
Average	-830.4E-12	-687.9E-12
Sigma	1.2E-09	1.1E-09

Drift Calculation

IR	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	162.40E-12
SN3	-	-1.76E-12
SN4	-	693.40E-12
SN5	-	2.50E-12
SN6	-	3.60E-12
SN7	-	-5.20E-12
Average	-	142.49E-12
Sigma	-	253.44E-12

Test conditions : Protons
Parameter : Current Transfer Ratio : CTR1
IF=1mA. VCE=5V
Unit :
No spec limit specified.



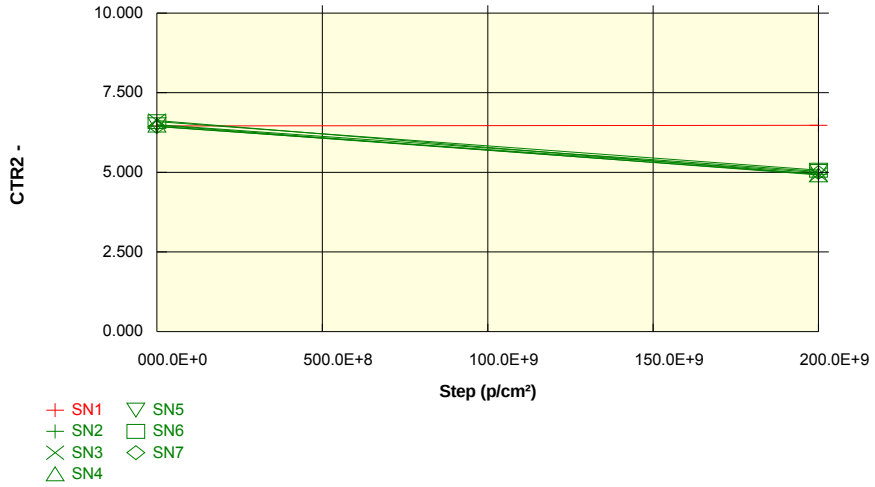
Measurements

CTR1	0 p/cm²	2E+11 p/cm²
SN1_REF	25.61	25.54
OFF samples		
SN2	25.52	10.12
SN3	27.80	9.91
SN4	26.96	10.80
SN5	25.67	10.61
SN6	26.07	10.57
SN7	25.73	10.78
Statistics		
Min	25.52	9.91
Max	27.80	10.80
Average	26.29	10.46
Sigma	0.82	0.33

Drift Calculation

CTR1	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	59.63E-03
SN3	-	64.93E-03
SN4	-	55.52E-03
SN5	-	55.34E-03
SN6	-	56.28E-03
SN7	-	53.88E-03
Average	-	57.60E-03
Sigma	-	3.72E-03

Test conditions : Protons
Parameter : Current Transfer Ratio : CTR2
IF=10mA. VCE=5V
Unit :
No spec limit specified.



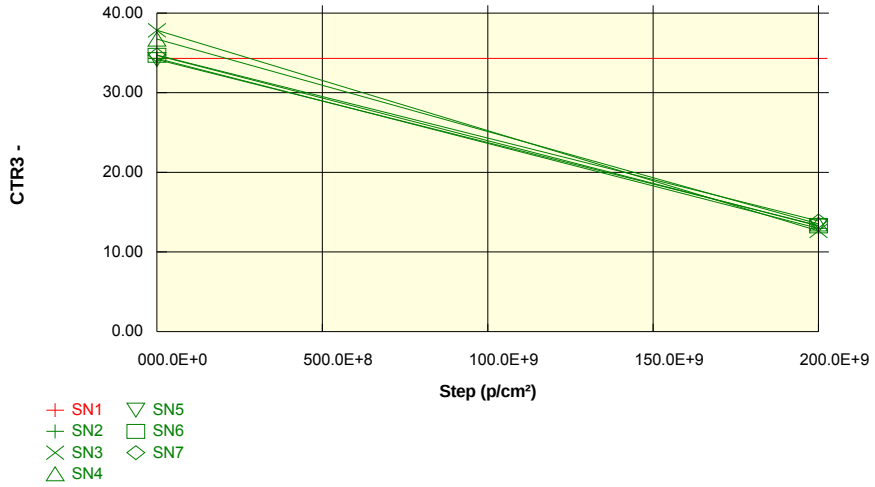
Measurements

CTR2	0 p/cm²	2E+11 p/cm²
SN1_REF	6.457	6.480
OFF samples		
SN2	6.449	4.940
SN3	6.627	4.936
SN4	6.486	4.920
SN5	6.496	5.031
SN6	6.594	5.071
SN7	6.438	4.995
Statistics		
Min	6.438	4.920
Max	6.627	5.071
Average	6.515	4.982
Sigma	0.071	0.055

Drift Calculation

CTR2	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	47.37E-03
SN3	-	51.70E-03
SN4	-	49.08E-03
SN5	-	44.85E-03
SN6	-	45.54E-03
SN7	-	44.86E-03
Average	-	47.23E-03
Sigma	-	2.50E-03

Test conditions : Protons
Parameter : Current Transfer Ratio : CTR3
IF=1mA. VCE=40V
Unit :
No spec limit specified.



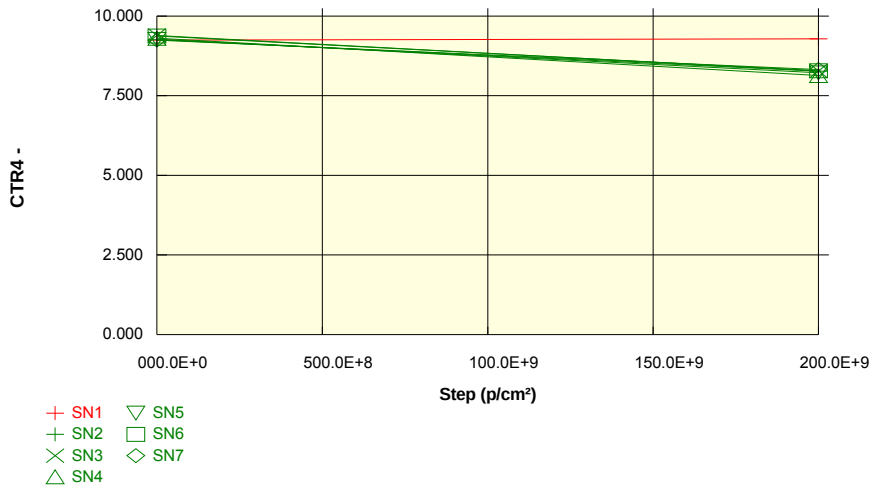
Measurements

CTR3	0 p/cm²	2E+11 p/cm²
SN1_REF	34.30	34.31
OFF samples		
SN2	34.30	12.96
SN3	37.85	12.64
SN4	36.73	13.51
SN5	34.17	13.34
SN6	34.69	13.26
SN7	34.73	13.89
Statistics		
Min	34.17	12.64
Max	37.85	13.89
Average	35.41	13.27
Sigma	1.38	0.39

Drift Calculation

CTR3	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	47.98E-03
SN3	-	52.68E-03
SN4	-	46.79E-03
SN5	-	45.68E-03
SN6	-	46.60E-03
SN7	-	43.21E-03
Average	-	47.16E-03
Sigma	-	2.87E-03

Test conditions : Protons
Parameter : Current Transfer Ratio : CTR4
IF=10mA. VCE=40V
Unit :
No spec limit specified.



Measurements

CTR4	0 p/cm²	2E+11 p/cm²
SN1_REF	9.246	9.287
OFF samples		
SN2	9.259	8.273
SN3	9.392	8.277
SN4	9.307	8.135
SN5	9.271	8.221
SN6	9.374	8.281
SN7	9.247	8.321
Statistics		
Min	9.247	8.135
Max	9.392	8.321
Average	9.308	8.251
Sigma	0.056	0.060

Drift Calculation

CTR4	0 p/cm²	2E+11 p/cm²
OFF samples		
SN2	-	12.87E-03
SN3	-	14.35E-03
SN4	-	15.48E-03
SN5	-	13.78E-03
SN6	-	14.07E-03
SN7	-	12.04E-03
Average	-	13.76E-03
Sigma	-	1.09E-03