TOTAL DOSE RADIATION TEST REPORT

Part Type : SPPX1N60S5

Package : TO-220

N-Channel Power MOSFET

SIEMENS

Report Reference : ESA_QCA9909012T_C

Issue : 01

Date : July 1st 1999

ESA Contract No 13413/98/NL/MV dated 25/01/99

European Space Agency Contract Report

The work described in this report was done under ESA contract.
Responsibility for the contents resides in the author or organization that prepared it

ESTEC Technical Officer: R. Harboe Sorensen

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TOTAL DOSE RADIATION TEST REPORT
on
Siemens SPPX1N60S5 N-Channel Power Mosfet.

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1 Abstract

Under ESA/ESTEC contract n° 13413/98/NL/MV covering "Radiation Evaluation of Power MOSFET Devices from Different European Manufacturers", a large number of commercial Power MOSFET device types were radiation assessed. Results from these assessments, primarily focused on the radiation sensitivity of the MOSFETs to Total Ionizing Dose (TID) and Single Event Effects (SEE), are reported in individual TID and SEE reports. Below summary table list manufacturer and evaluated types, and give references to the various reports issued.

Manufacturer	Type	TID Report	SEE Report
Philips	PHP50N06T	ESA_QCA990901T_C	ESA_QCA990901S_C
Philips	BUK456-200A	ESA_QCA990902T_C	ESA_QCA990902S_C
Motorola	MTP50N06VL	ESA_QCA990903T_C	
Motorola	MTW32N20E	ESA_QCA990904T_C	
Motorola	MTP50N06V	ESA_QCA990905T_C	
Siemens	BUZ100S	ESA_QCA990906T_C	ESA_QCA990906S_C
Siemens	BUZ100SL	ESA_QCA990907T_C	ESA_QCA990907S_C
Siemens	BUZ341	ESA_QCA990908T_C	ESA_QCA990908S_C
SGS-Thomson	SP60	ESA_QCA990909T_C	ESA_QCA990909S_C
SGS-Thomson	SP100V	ESA_QCA9909010T_C	ESA_QCA9909010S_C
SGS-Thomson	SP200V	ESA_QCA9909011T_C	ESA_QCA9909011S_C
Siemens	SPPX1N60S5	ESA_QCA9909012T_C	ESA_QCA9909012S_C
Philips	BUK7508-55	ESA_QCA9909013T_C	ESA_QCA9909013S_C
Harris	HUF75639P3	ESA_QCA9909014T_C	ESA_QCA9909014S_C

2 Introduction

A total dose radiation evaluation test of the SIEMENS SPPX1N60S5 N-Channel Power Mosfet has been performed with an accumulated dose of about 37 Krad(Si) at a dose rate of 75 rad(Si)/hour, in response to European Space Agency contract reference : 13413/98/NL/MV.

The purpose of this test was to evaluate total dose withstanding of this component, to investigate its suitability for being used in space applications. This test was conducted on commercial samples provided by ESTEC.
Test has been performed in accordance with Hirex proposal HRX/98.3475 issue 01.

A complete set of electrical measurements together with graphical representation of measured parameters with respect to total dose received, are provided for all samples.

SEE results for this device type can be found in SEE radiation test report: ESA_QCA9909012S_C

3 Applicable and Reference Documents

3.1 Applicable Documents

- ESA/SCC Basic specification N° 22900 issue 4
- Siemens datasheet (See Annex)
- Hirex Engineering proposal: HRX/98.3475 issue 01.

3.2 Reference Documents

- MIL-STD-883: test methods and procedures for microcircuits

4 Test Samples

10 samples of the SPPX1N60S5 device were tested (1 group of 5 and 1 group of 4 + 1 control sample). The samples were serialized before the radiation test as indicated in the following table.

Serial Number	Allocation
1	Control
2	Bias 2
3	Bias 2
4	Bias 2
5	Bias 2
6	Bias 2
7	Bias 1
8	Bias 1
9	Bias 1
10	Bias 1

Identification of the SPPX1N60S5 is given below:

Part Number:	SPPX1N60S5	**Mask Set:**	NA
Top Marking:	20N60N5 A910	**Chip Marking:**	NA
Diffusion Lot:	NA	**Wafer #:**	NA
Date Code:	A910	**Project:**	Not defined

5 Experimental Conditions

5.1 Radiation Source Dose Rate and Annealing

The dose exposures were performed at CERT-ONERA. In this irradiation facility, a Cobalt 60 source is used with the possibility to vary the dose rate by simply adjusting the distance to the source.
The irradiation conditions used for this test are provided in the following table:

Irradiation Steps	**Dose rate**	**Annealing steps**	**Temperature**
krads	**krads/h**	**hours**	**°C**
0			
3.85	0,075		25
7.35	0,075		25
13.95	0,075		25
19.65	0,075		25
24.65	0,075		25
29.85	0,075		25
36.85	0,075	0	25
		24	25
		192	100

5.2 Bias during Dose Exposures and Measurements conditions

5.2.1 Bias conditions

During exposures dedicated test boards were used mounted on a special board-holder made for irradiation. The test board allowed to bias the devices in accordance with the electrical circuit provided in Figure 1. Two bias conditions were used so called Bias 1 and Bias 2.
Bias 1 corresponds to a gate stress of VGSS equals 12 Volts. Bias 2 corresponds to drain to source stress equals 80% of BVDSS.
During annealing steps the same stress conditions were applied at room and 100°C temperatures respectively.

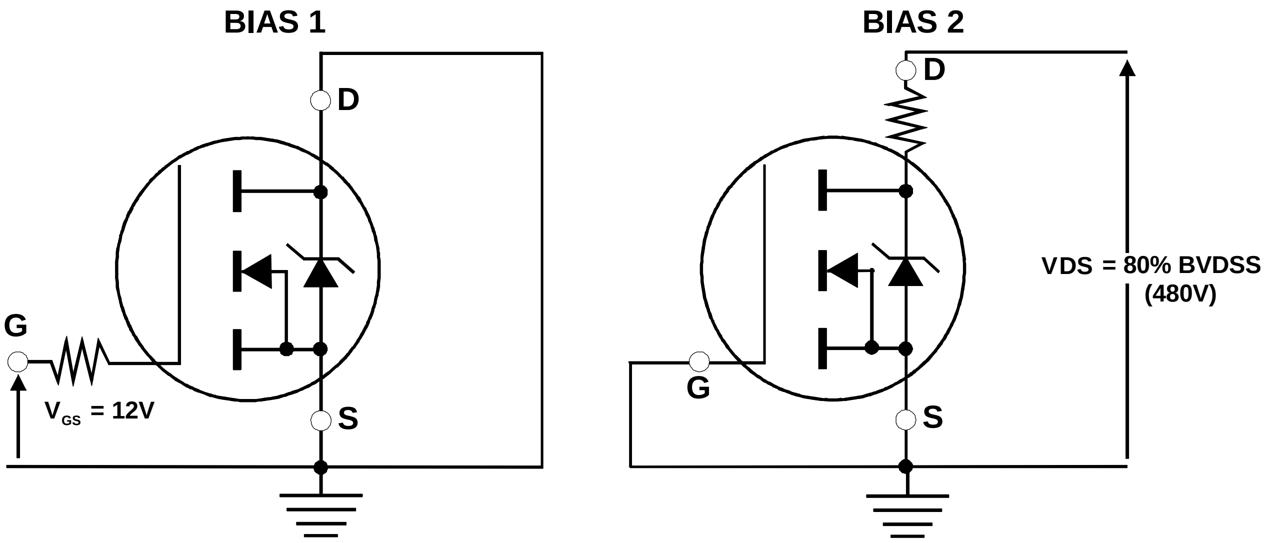


Figure 1 : Bias Conditions during Irradiation Exposures and Annealing

5.2.2 Electrical Measurements

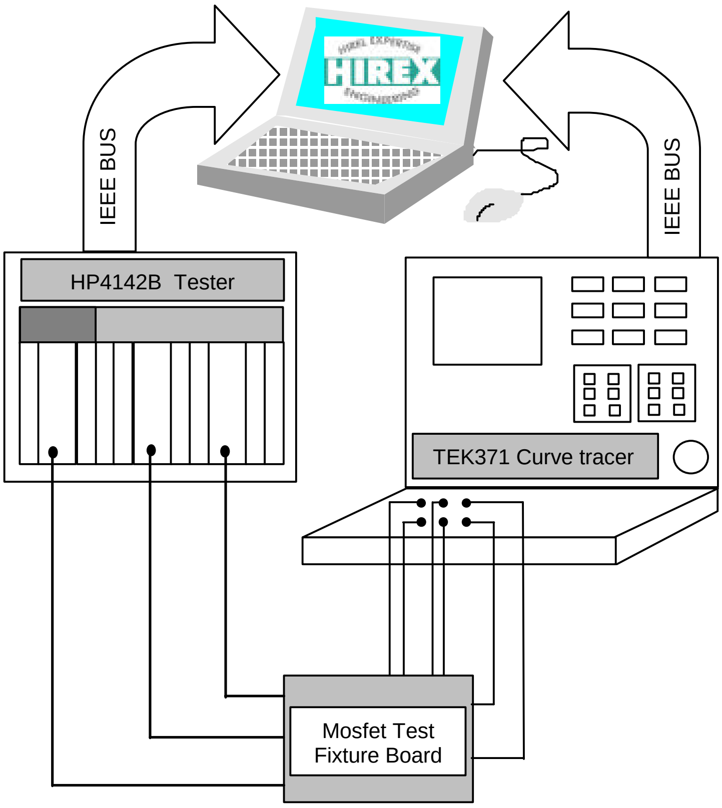
Mosfet transistor test program principle is provided in Figure 2. Due to the great number of samples to be measured (test campaign was conducted on 14 part types at the same time) and the time interval constraints required for performing measurements after each exposure and annealing step, It was decided to automate low power and high power measurements.

Two instruments were used to cover low power and high power measurements respectively.
HP4142B was used for breakdown voltage, gate and drain leakage currents, and threshold voltage measurements.
Tektronix TEK371 high power curve tracer was used for R_{DSON} measurements.

A dedicated test fixture was designed to ensure proper switching of instruments. In addition a faraday cup was used to ensure optimum conditions for low level measurements.

Test program has been written in Visual Basic on a PC computer. HPIB commands were sent to each instrument via IEEE bus, in order to measure a given parameter with specified conditions.
Results were automatically loaded in an Excel worksheet and compared in real time to specification limits. This allowed for real time data analysis in particular when failures were recorded.

Figure 2 : Mosfet transistor test program principle



Electrical parameters test conditions and limits used for performing this test are given in the following table.

Symbol	**Test Parameter**	**Test Conditions**	**Min limit**	**Max limit**	**Unit**
BVDSS	Drain to Source breakdown voltage	VGS=0V, ID=0.25mA	600		V
VGSTH	Gate to Source threshold voltage	VDS>=VGS, ID=1mA	3.5	6	V
+IGSS	Positive Gate Source leakage current	VGS=+20V, VDS=0V		100	nA
-IGSS	Negative Gate Source leakage current	VGS=-20V, VDS=0V		100	nA
IDSS	Drain current	VGS=0V, VDS=600V		1	µA
RDSON	Static drain to source on-state resistance	VGS=10V, ID=13.1A		0.190	Ohm

Table 1 : Measured electrical parameters

6 Test Summary

A Total Ionizing Dose assessment was carried out by Hirex Engineering under ESA contract on the SIEMENS SPPX1AN60S5 N-Channel Power Mosfet.
2 groups of 5 samples each plus one control sample were used during testing. The first group was exposed to radiation using Bias 1 conditions corresponding to a gate stress of the devices. The second group of 5 samples was exposed to radiation using Bias 2 conditions corresponding to drain to source stress of the devices, equals 80% of BVDSS (480 Volts).

Based on the analysis of the results, the tolerances of this component and main conclusion are provided below.

Parametric Tolerance Level (>=Krad) - Bias 1:	7.35
Parametric Tolerance Level (>=Krad) - Bias 2:	7.35

Parametric tolerance level represents the last cumulative exposure at which no samples failed any test

Main conclusion:

This device exhibits a dramatic drop in breakdown voltage, after first annealing step under Bias 2 conditions. No significant recovery is observed afterwards.
Gate leakage current has increased (up to the compliance value of 1mA) after 24H annealing, for Bias 2 conditions.
Threshold voltage is out of specification at 13.95 Krad(Si) for both bias conditions.

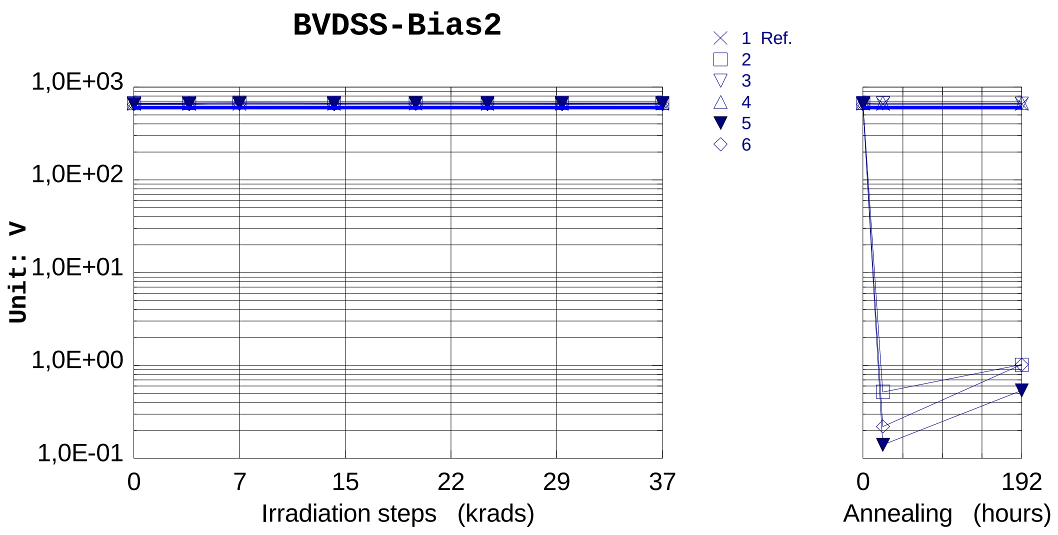
7 Test Results

Test results including tables and graphics are provided in this section for each measured parameter. To allow easy reading of data, each parameter is plotted twice, one for the first bias condition: Bias 1 and one for the second condition: Bias 2.

Parameter: Drain to source breakdown voltage: BVDSS-Bias2 VGS=0V, ID=0.25mA
Unit= V
Spec limit min: 600
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	6,521E +02	6,510E +02	6,540E +02	6,539E +02	6,557E +02	6,517E +02	6,514E +02
2	6,670E +02	6,706E +02	6,746E +02	6,700E +02	6,718E +02	6,698E +02	6,693E +02
3	6,601E +02	6,607E +02	6,659E +02	6,628E +02	6,649E +02	6,634E +02	6,623E +02
4	6,687E +02	6,695E +02	6,755E +02	6,716E +02	6,746E +02	6,727E +02	6,715E +02
5	6,518E +02	6,529E +02	6,583E +02	6,546E +02	6,580E +02	6,550E +02	6,545E +02
6	6,504E +02	6,508E +02	6,560E +02	6,523E +02	6,552E +02	6,537E +02	6,527E +02
Statistics							
Min	6,504E +02	6,508E +02	6,560E +02	6,523E +02	6,552E +02	6,537E +02	6,527E +02
Max	6,687E +02	6,706E +02	6,755E +02	6,716E +02	6,746E +02	6,727E +02	6,715E +02
Mean	6,596E +02	6,609E +02	6,661E +02	6,622E +02	6,649E +02	6,629E +02	6,621E +02
Sigma	8,437E +00	9,159E +00	8,997E +00	8,732E +00	8,435E +00	8,535E +00	8,473E +00

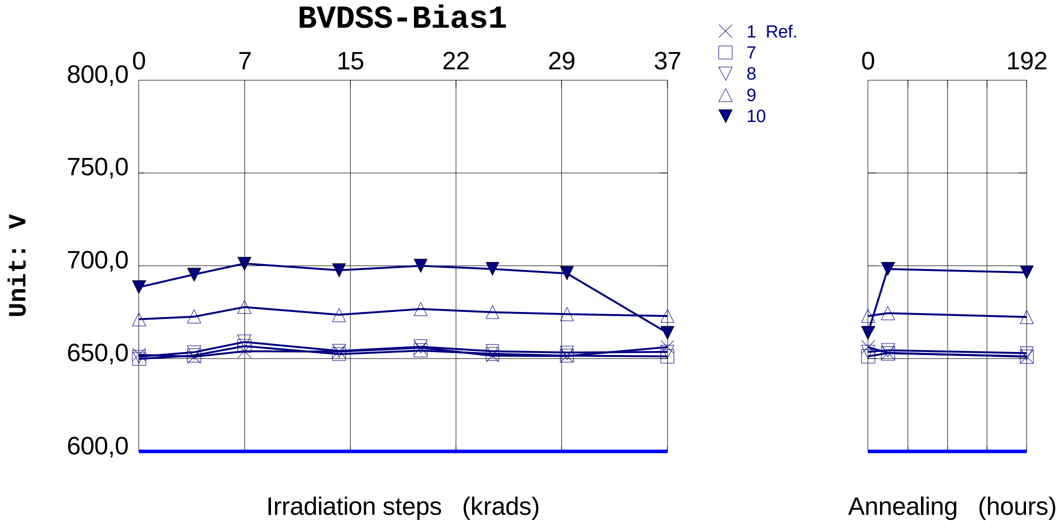
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	6,563E +02	6,531E +02	6,510E +02
2	6,694E +02	5,200E -01	1,020E +00
3	6,622E +02	6,646E +02	6,610E +02
4	6,713E +02	6,732E +02	6,716E +02
5	6,543E +02	1,400E -01	5,400E -01
6	6,528E +02	2,200E -01	1,020E +00
Statistics			
Min	6,528E +02	1,400E -01	5,400E -01
Max	6,713E +02	6,732E +02	6,716E +02
Mean	6,620E +02	2,677E +02	2,670E +02
Sigma	8,445E +00	3,662E +02	3,645E +02



Parameter: Drain to source breakdown voltage: BVDSS-Bias1 VGS=0V, ID=0.25mA
Unit= V
Spec limit min: 600
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	6,521E +02	6,510E +02	6,540E +02	6,539E +02	6,557E +02	6,517E +02	6,514E +02
7	6,499E +02	6,517E +02	6,568E +02	6,524E +02	6,544E +02	6,525E +02	6,516E +02
8	6,510E +02	6,533E +02	6,590E +02	6,541E +02	6,565E +02	6,540E +02	6,532E +02
9	6,712E +02	6,727E +02	6,778E +02	6,735E +02	6,766E +02	6,750E +02	6,740E +02
10	6,885E +02	6,952E +02	7,011E +02	6,976E +02	7,000E +02	6,983E +02	6,960E +02
Statistics							
Min	6,499E +02	6,517E +02	6,568E +02	6,524E +02	6,544E +02	6,525E +02	6,516E +02
Max	6,885E +02	6,952E +02	7,011E +02	6,976E +02	7,000E +02	6,983E +02	6,960E +02
Mean	6,651E +02	6,682E +02	6,737E +02	6,694E +02	6,719E +02	6,700E +02	6,687E +02
Sigma	1,840E +01	2,034E +01	2,058E +01	2,107E +01	2,126E +01	2,149E +01	2,085E +01

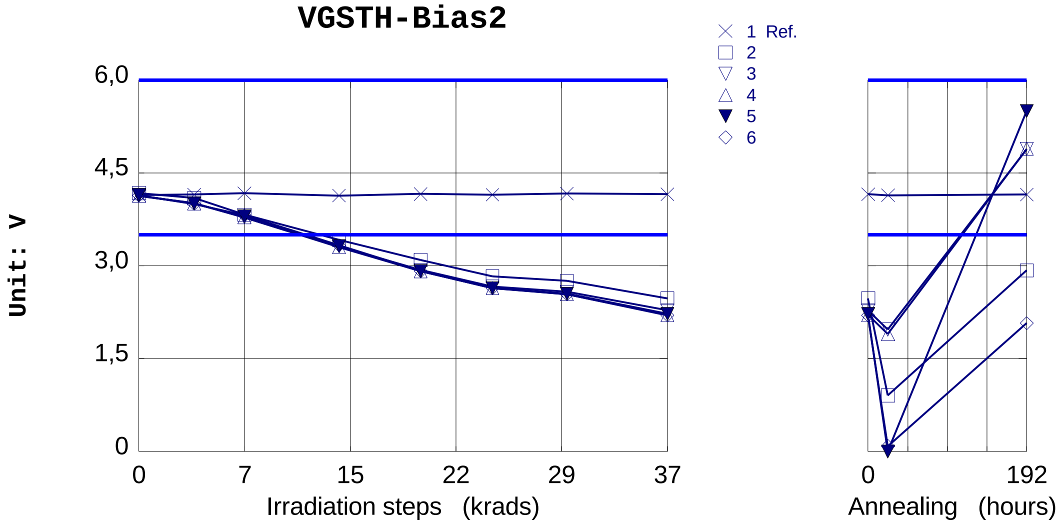
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	6,563E +02	6,531E +02	6,510E +02
7	6,513E +02	6,529E +02	6,511E +02
8	6,536E +02	6,545E +02	6,528E +02
9	6,730E +02	6,744E +02	6,724E +02
10	6,638E +02	6,983E +02	6,964E +02
Statistics			
Min	6,513E +02	6,529E +02	6,511E +02
Max	6,730E +02	6,983E +02	6,964E +02
Mean	6,604E +02	6,700E +02	6,682E +02
Sigma	9,983E +00	2,127E +01	2,116E +01



Parameter: Gate to source threshold voltage: VGSTH-Bias2 **VDS>=VGS, ID=1mA**
Unit= V
Spec limit max: 6
Spec limit min: 3.5
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	4,143E +00	4,151E +00	4,171E +00	4,132E +00	4,159E +00	4,148E +00	4,165E +00
2	4,173E +00	4,092E +00	3,824E +00	3,417E +00	3,092E +00	2,831E +00	2,755E +00
3	4,129E +00	4,011E +00	3,781E +00	3,309E +00	2,932E +00	2,663E +00	2,579E +00
4	4,130E +00	4,006E +00	3,780E +00	3,301E +00	2,909E +00	2,640E +00	2,539E +00
5	4,140E +00	4,003E +00	3,800E +00	3,319E +00	2,912E +00	2,636E +00	2,547E +00
6	4,136E +00	3,999E +00	3,815E +00	3,328E +00	2,913E +00	2,638E +00	2,539E +00
Statistics							
Min	4,129E +00	3,999E +00	3,780E +00	3,301E +00	2,909E +00	2,636E +00	2,539E +00
Max	4,173E +00	4,092E +00	3,824E +00	3,417E +00	3,092E +00	2,831E +00	2,755E +00
Mean	4,142E +00	4,022E +00	3,800E +00	3,335E +00	2,952E +00	2,682E +00	2,592E +00
Sigma	1,829E -02	3,920E -02	1,978E -02	4,723E -02	7,883E -02	8,422E -02	9,285E -02

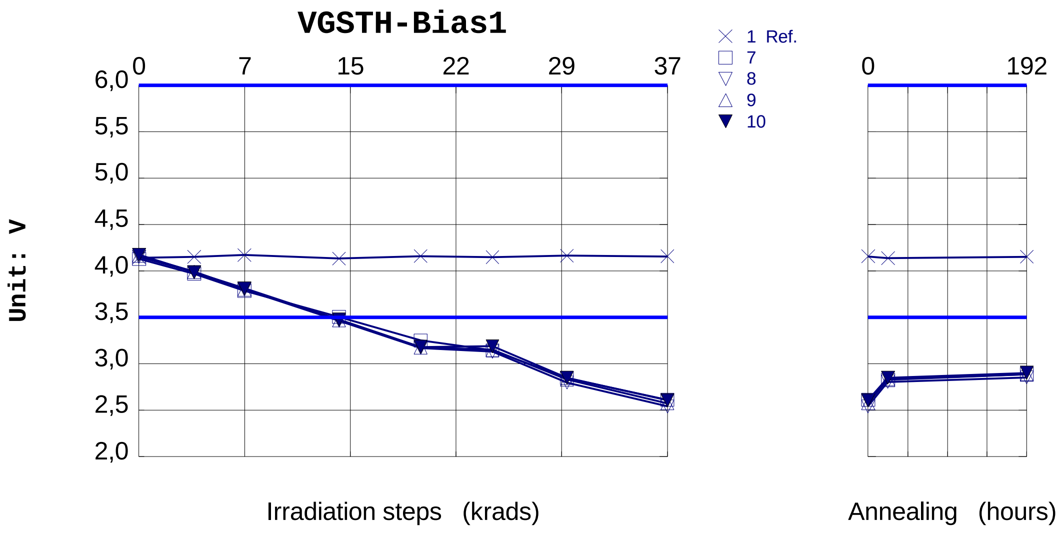
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	4,157E +00	4,137E +00	4,153E +00
2	2,472E +00	9,050E -01	2,924E +00
3	2,278E +00	1,970E +00	4,885E +00
4	2,206E +00	1,898E +00	4,890E +00
5	2,221E +00	0,000E +00	5,500E +00
6	2,200E +00	8,688E -02	2,073E +00
Statistics			
Min	2,200E +00	0,000E +00	2,073E +00
Max	2,472E +00	1,970E +00	5,500E +00
Mean	2,276E +00	9,721E -01	4,054E +00
Sigma	1,141E -01	9,470E -01	1,473E +00



Parameter: Gate to source threshold voltage: VGSTH-Bias1 **VDS>=VGS,ID=1mA**
Unit= V
Spec limit max: 6
Spec limit min: 3.5
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	4,143E +00	4,151E +00	4,171E +00	4,132E +00	4,159E +00	4,148E +00	4,165E +00
7	4,130E +00	3,969E +00	3,785E +00	3,504E +00	3,251E +00	3,145E +00	2,847E +00
8	4,151E +00	3,989E +00	3,800E +00	3,462E +00	3,170E +00	3,131E +00	2,798E +00
9	4,164E +00	3,990E +00	3,799E +00	3,467E +00	3,175E +00	3,149E +00	2,831E +00
10	4,173E +00	3,985E +00	3,812E +00	3,477E +00	3,181E +00	3,189E +00	2,850E +00
Statistics							
Min	4,130E +00	3,969E +00	3,785E +00	3,462E +00	3,170E +00	3,131E +00	2,798E +00
Max	4,173E +00	3,990E +00	3,812E +00	3,504E +00	3,251E +00	3,189E +00	2,850E +00
Mean	4,154E +00	3,983E +00	3,799E +00	3,477E +00	3,195E +00	3,154E +00	2,831E +00
Sigma	1,867E -02	9,665E -03	1,111E -02	1,895E -02	3,795E -02	2,491E -02	2,395E -02

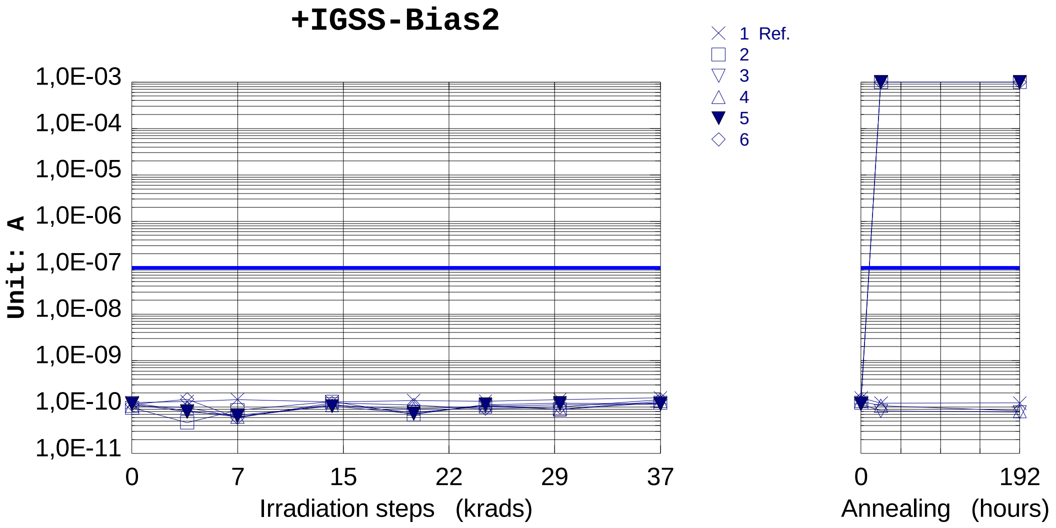
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	4,157E +00	4,137E +00	4,153E +00
7	2,612E +00	2,826E +00	2,889E +00
8	2,541E +00	2,806E +00	2,852E +00
9	2,573E +00	2,835E +00	2,884E +00
10	2,606E +00	2,850E +00	2,902E +00
Statistics			
Min	2,541E +00	2,806E +00	2,852E +00
Max	2,612E +00	2,850E +00	2,902E +00
Mean	2,583E +00	2,829E +00	2,882E +00
Sigma	3,273E -02	1,841E -02	2,115E -02



Parameter: Positive Gate source leakage current: +IGSS-Bias2 VGS=+20V, VDS=0V
Unit= A
Spec limit max: 100E-9
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	1,251E -10	1,326E -10	1,454E -10	1,276E -10	1,384E -10	1,343E -10	1,454E -10
2	9,720E -11	4,652E -11	8,642E -11	1,305E -10	6,896E -11	1,126E -10	8,900E -11
3	1,227E -10	8,224E -11	6,134E -11	1,146E -10	7,680E -11	1,029E -10	1,121E -10
4	1,058E -10	9,640E -11	6,116E -11	1,088E -10	9,134E -11	1,034E -10	8,946E -11
5	1,166E -10	7,946E -11	6,642E -11	1,042E -10	7,184E -11	1,130E -10	1,216E -10
6	1,136E -10	1,473E -10	5,854E -11	1,233E -10	1,109E -10	9,212E -11	9,954E -11
Statistics							
Min	9,720E -11	4,652E -11	5,854E -11	1,042E -10	6,896E -11	9,212E -11	8,900E -11
Max	1,227E -10	1,473E -10	8,642E -11	1,305E -10	1,109E -10	1,130E -10	1,216E -10
Mean	1,112E -10	9,039E -11	6,678E -11	1,163E -10	8,396E -11	1,048E -10	1,023E -10
Sigma	9,897E -12	3,671E -11	1,135E -11	1,068E -11	1,734E -11	8,579E -12	1,429E -11

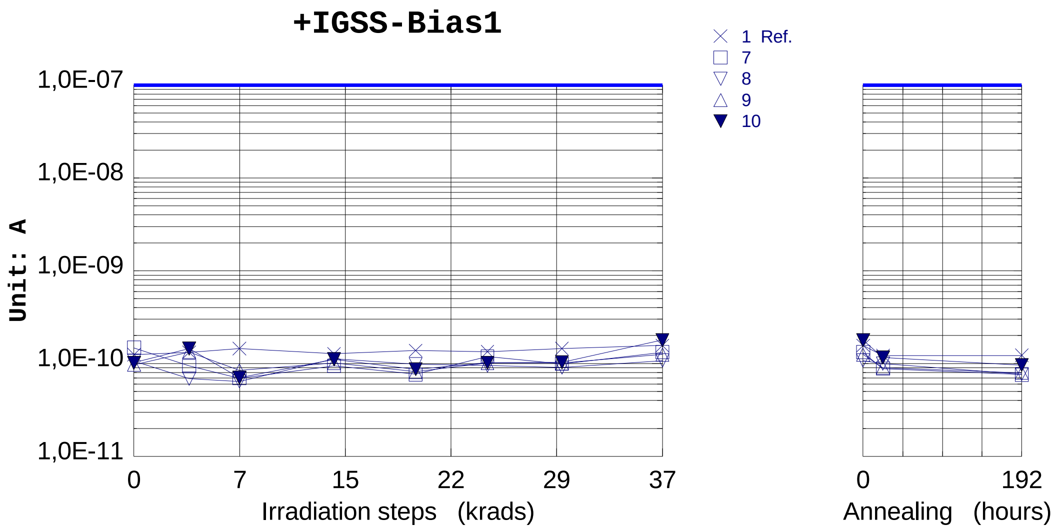
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	1,572E -10	1,217E -10	1,224E -10
2	1,244E -10	1,000E -03	1,000E -03
3	1,153E -10	8,258E -11	7,750E -11
4	1,340E -10	1,070E -10	8,210E -11
5	1,183E -10	1,000E -03	1,000E -03
6	1,444E -10	1,000E -03	1,000E -03
Statistics			
Min	1,153E -10	8,258E -11	7,750E -11
Max	1,444E -10	1,000E -03	1,000E -03
Mean	1,273E -10	6,000E -04	6,000E -04
Sigma	1,197E -11	5,478E -04	5,477E -04



Parameter: Positive Gate source leakage current: +IGSS-Bias1 VGS=+20V, VDS=0V
Unit= A
Spec limit max: 100E-9
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	1,251E -10	1,326E -10	1,454E -10	1,276E -10	1,384E -10	1,343E -10	1,454E -10
7	1,483E -10	9,410E -11	6,982E -11	9,458E -11	7,644E -11	1,196E -10	9,932E -11
8	1,073E -10	6,884E -11	6,414E -11	1,127E -10	9,852E -11	9,546E -11	9,098E -11
9	9,712E -11	1,340E -10	8,452E -11	1,016E -10	8,178E -11	1,018E -10	1,013E -10
10	1,020E -10	1,451E -10	7,058E -11	1,106E -10	8,692E -11	1,024E -10	1,034E -10
Statistics							
Min	9,712E -11	6,884E -11	6,414E -11	9,458E -11	7,644E -11	9,546E -11	9,098E -11
Max	1,483E -10	1,451E -10	8,452E -11	1,127E -10	9,852E -11	1,196E -10	1,034E -10
Mean	1,137E -10	1,105E -10	7,226E -11	1,049E -10	8,591E -11	1,048E -10	9,875E -11
Sigma	2,347E -11	3,536E -11	8,661E -12	8,364E -12	9,430E -12	1,035E -11	5,442E -12

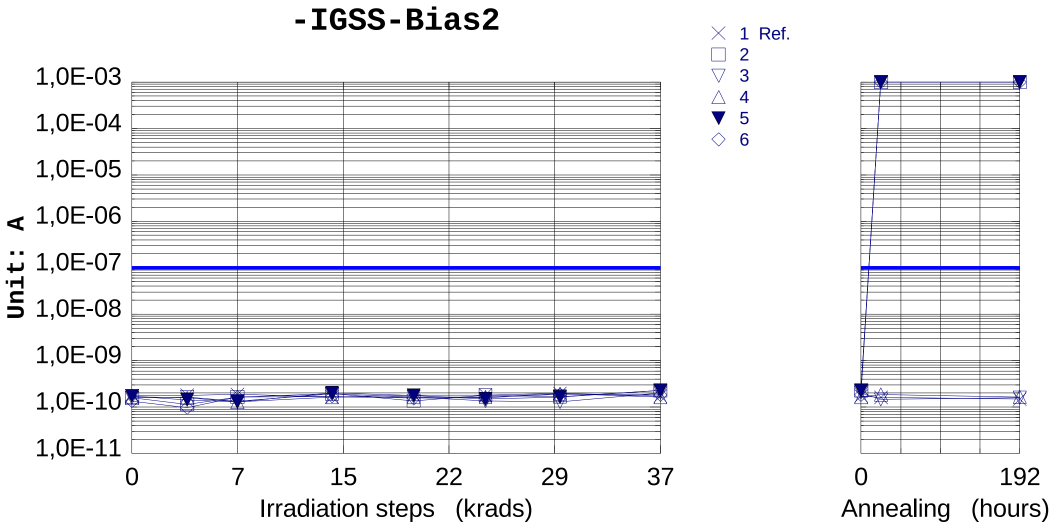
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	1,572E -10	1,217E -10	1,224E -10
7	1,330E -10	8,824E -11	7,588E -11
8	1,081E -10	9,976E -11	7,714E -11
9	1,254E -10	9,040E -11	7,962E -11
10	1,790E -10	1,162E -10	9,652E -11
Statistics			
Min	1,081E -10	8,824E -11	7,588E -11
Max	1,790E -10	1,162E -10	9,652E -11
Mean	1,364E -10	9,866E -11	8,229E -11
Sigma	3,027E -11	1,274E -11	9,613E -12



Parameter: Negative Gate source leakage current: -IGSS-Bias2 VGS=-20V, VDS=0V
Unit= A
Spec limit max: 100E-9
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	1,748E -10	1,789E -10	1,872E -10	1,642E -10	1,806E -10	1,798E -10	1,974E -10
2	1,571E -10	1,141E -10	1,651E -10	1,946E -10	1,362E -10	1,794E -10	1,682E -10
3	1,590E -10	1,654E -10	1,345E -10	1,901E -10	1,650E -10	1,357E -10	1,286E -10
4	1,667E -10	1,578E -10	1,293E -10	1,642E -10	1,635E -10	1,653E -10	1,937E -10
5	1,730E -10	1,434E -10	1,289E -10	2,012E -10	1,778E -10	1,500E -10	1,634E -10
6	1,342E -10	9,752E -11	1,639E -10	1,700E -10	1,547E -10	1,587E -10	1,876E -10
Statistics							
Min	1,342E -10	9,752E -11	1,289E -10	1,642E -10	1,362E -10	1,357E -10	1,286E -10
Max	1,730E -10	1,654E -10	1,651E -10	2,012E -10	1,778E -10	1,794E -10	1,937E -10
Mean	1,580E -10	1,356E -10	1,444E -10	1,840E -10	1,594E -10	1,578E -10	1,683E -10
Sigma	1,472E -11	2,895E -11	1,855E -11	1,609E -11	1,536E -11	1,637E -11	2,559E -11

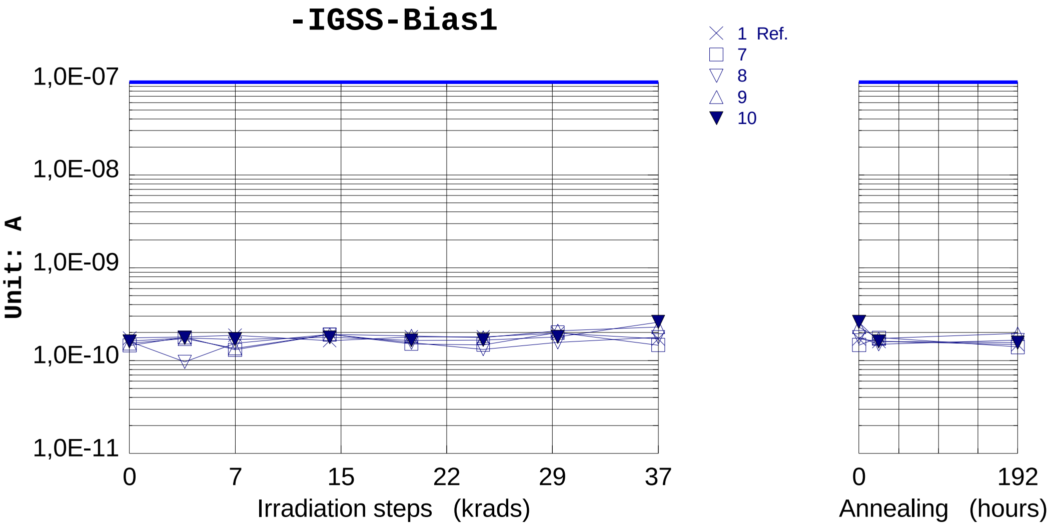
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	1,722E -10	1,611E -10	1,488E -10
2	2,302E -10	1,000E -03	1,000E -03
3	2,039E -10	1,461E -10	1,588E -10
4	1,627E -10	1,865E -10	1,661E -10
5	2,272E -10	1,000E -03	1,000E -03
6	1,834E -10	1,000E -03	1,000E -03
Statistics			
Min	1,627E -10	1,461E -10	1,588E -10
Max	2,302E -10	1,000E -03	1,000E -03
Mean	2,015E -10	6,001E -04	6,000E -04
Sigma	2,884E -11	5,478E -04	5,477E -04



Parameter: Negative Gate source leakage current: -IGSS-Bias1 VGS=-20V, VDS=0V
Unit= A
Spec limit max: 100E-9
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	1,748E -10	1,789E -10	1,872E -10	1,642E -10	1,806E -10	1,798E -10	1,974E -10
7	1,459E -10	1,783E -10	1,303E -10	1,913E -10	1,519E -10	1,485E -10	2,012E -10
8	1,608E -10	9,696E -11	1,535E -10	1,918E -10	1,563E -10	1,325E -10	1,574E -10
9	1,532E -10	1,725E -10	1,355E -10	1,919E -10	1,843E -10	1,773E -10	2,094E -10
10	1,618E -10	1,761E -10	1,695E -10	1,778E -10	1,652E -10	1,665E -10	1,798E -10
Statistics							
Min	1,459E -10	9,696E -11	1,303E -10	1,778E -10	1,519E -10	1,325E -10	1,574E -10
Max	1,618E -10	1,783E -10	1,695E -10	1,919E -10	1,843E -10	1,773E -10	2,094E -10
Mean	1,554E -10	1,560E -10	1,472E -10	1,882E -10	1,644E -10	1,562E -10	1,870E -10
Sigma	7,433E -12	3,941E -11	1,787E -11	6,971E -12	1,435E -11	1,977E -11	2,334E -11

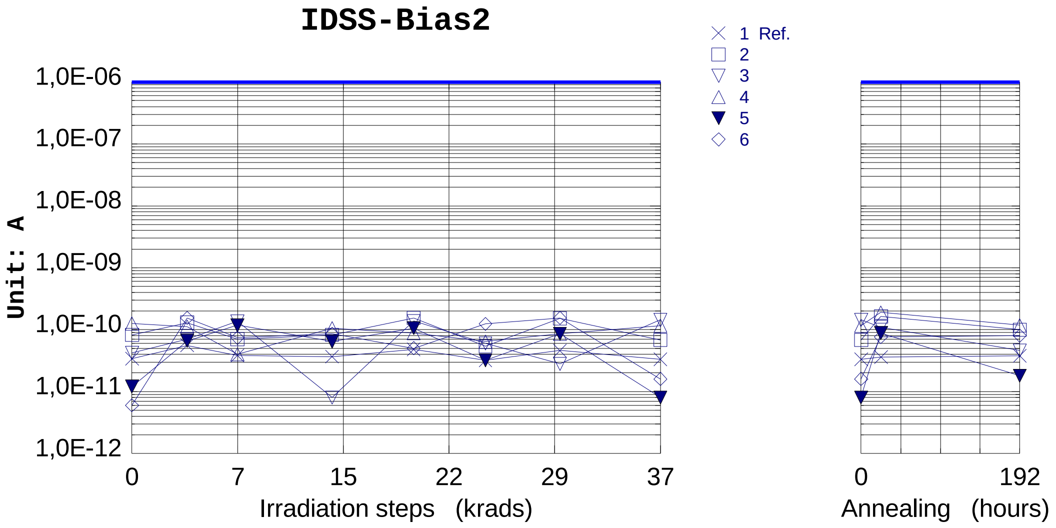
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	1,722E -10	1,611E -10	1,488E -10
7	1,472E -10	1,764E -10	1,403E -10
8	1,784E -10	1,498E -10	1,669E -10
9	2,301E -10	1,726E -10	1,955E -10
10	2,601E -10	1,610E -10	1,563E -10
Statistics			
Min	1,472E -10	1,498E -10	1,403E -10
Max	2,601E -10	1,764E -10	1,955E -10
Mean	2,040E -10	1,650E -10	1,648E -10
Sigma	5,068E -11	1,204E -11	2,325E -11



Parameter: Drain current: IDSS-Bias2 VGS=0V, VDS=600V
Unit= A
Spec limit max: 1E-6
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	3,400E -11	5,600E -11	3,840E -11	3,660E -11	4,800E -11	3,200E -11	4,600E -11
2	8,200E -11	1,300E -10	7,000E -11	8,200E -11	1,540E -10	5,400E -11	1,520E -10
3	4,200E -11	7,000E -11	1,360E -10	8,000E -12	1,380E -10	6,000E -11	2,800E -11
4	1,260E -10	1,120E -10	4,000E -11	1,060E -10	8,800E -11	6,400E -11	8,600E -11
5	1,200E -11	6,600E -11	1,180E -10	6,400E -11	1,060E -10	3,200E -11	8,600E -11
6	6,000E -12	1,540E -10	7,400E -11	8,600E -11	5,000E -11	1,240E -10	1,540E -10
Statistics							
Min	6,000E -12	6,600E -11	4,000E -11	8,000E -12	5,000E -11	3,200E -11	2,800E -11
Max	1,260E -10	1,540E -10	1,360E -10	1,060E -10	1,540E -10	1,240E -10	1,540E -10
Mean	5,360E -11	1,064E -10	8,760E -11	6,920E -11	1,072E -10	6,680E -11	1,012E -10
Sigma	5,045E -11	3,812E -11	3,882E -11	3,733E -11	4,117E -11	3,428E -11	5,289E -11

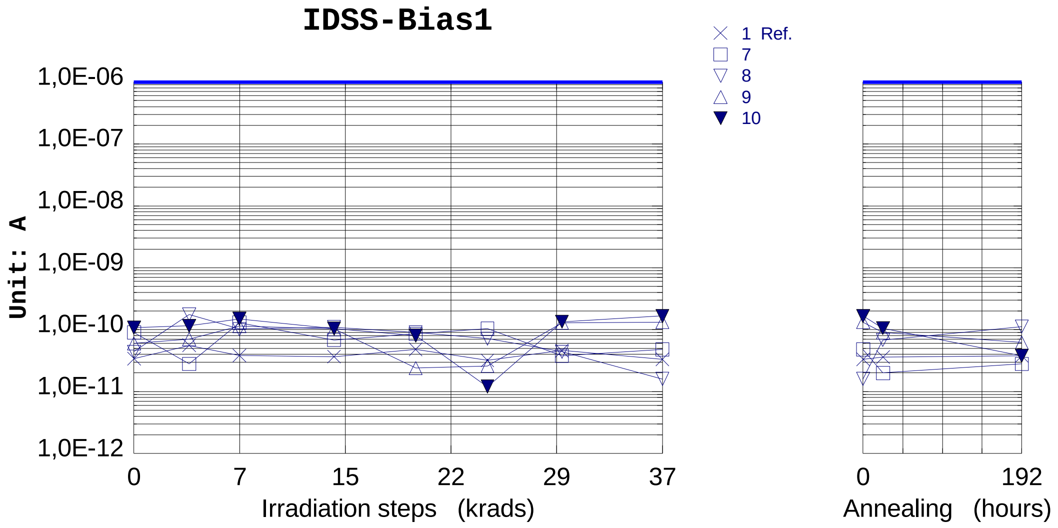
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	3,320E -11	3,600E -11	3,800E -11
2	6,800E -11	1,640E -10	1,000E -10
3	1,440E -10	1,100E -10	4,600E -11
4	1,160E -10	1,900E -10	1,180E -10
5	8,000E -12	8,800E -11	1,800E -11
6	1,600E -11	7,600E -11	8,000E -11
Statistics			
Min	8,000E -12	7,600E -11	1,800E -11
Max	1,440E -10	1,900E -10	1,180E -10
Mean	7,040E -11	1,256E -10	7,240E -11
Sigma	5,991E -11	4,934E -11	4,048E -11



Parameter: Drain current: IDSS-Bias1 VGS=0V, VDS=600V
Unit= A
Spec limit max: 1E-6
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	3,400E -11	5,600E -11	3,840E -11	3,660E -11	4,800E -11	3,200E -11	4,600E -11
7	9,000E -11	2,800E -11	1,300E -10	6,800E -11	8,600E -11	1,040E -10	3,800E -11
8	4,400E -11	1,760E -10	1,020E -10	1,100E -10	9,000E -11	7,200E -11	4,400E -11
9	6,000E -11	7,000E -11	1,140E -10	1,020E -10	2,400E -11	2,600E -11	1,300E -10
10	1,080E -10	1,160E -10	1,500E -10	1,040E -10	8,000E -11	1,200E -11	1,340E -10
Statistics							
Min	4,400E -11	2,800E -11	1,020E -10	6,800E -11	2,400E -11	1,200E -11	3,800E -11
Max	1,080E -10	1,760E -10	1,500E -10	1,100E -10	9,000E -11	1,040E -10	1,340E -10
Mean	7,550E -11	9,750E -11	1,240E -10	9,600E -11	7,000E -11	5,350E -11	8,650E -11
Sigma	2,886E -11	6,348E -11	2,078E -11	1,897E -11	3,094E -11	4,231E -11	5,262E -11

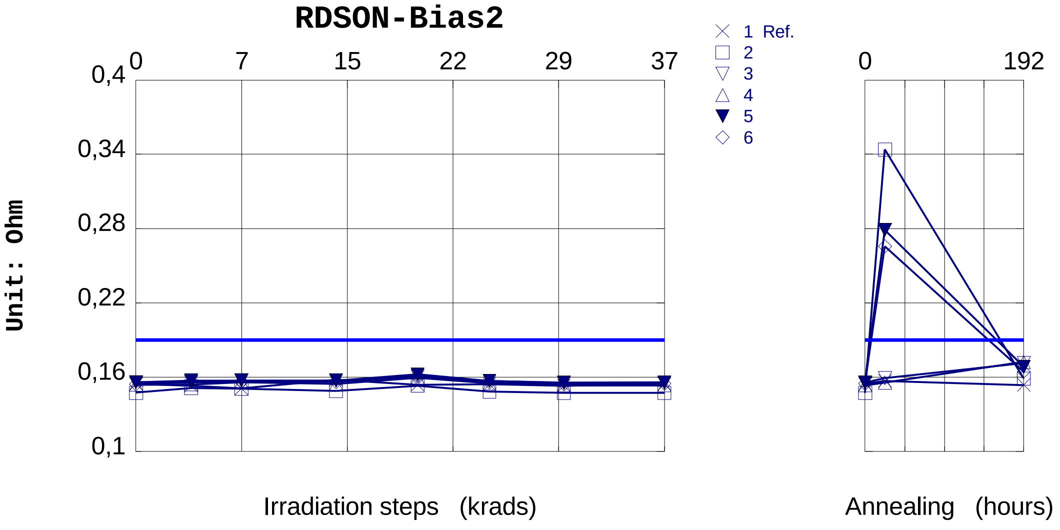
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	3,320E -11	3,600E -11	3,800E -11
7	4,800E -11	2,000E -11	2,800E -11
8	1,600E -11	6,800E -11	1,120E -10
9	1,320E -10	9,000E -11	6,200E -11
10	1,660E -10	1,060E -10	3,800E -11
Statistics			
Min	1,600E -11	2,000E -11	2,800E -11
Max	1,660E -10	1,060E -10	1,120E -10
Mean	9,050E -11	7,100E -11	6,000E -11
Sigma	7,019E -11	3,740E -11	3,749E -11



Parameter: Static drain to source on-state resistance: RDSON-Bias2 **VGS=10V, ID=13,1A**
Unit= Ohm
Spec limit max: 0.1
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	1,546E -01	1,531E -01	1,510E -01	1,579E -01	1,538E -01	1,542E -01	1,531E -01
2	1,475E -01	1,512E -01	1,506E -01	1,488E -01	1,531E -01	1,483E -01	1,473E -01
3	1,560E -01	1,562E -01	1,573E -01	1,573E -01	1,608E -01	1,569E -01	1,554E -01
4	1,538E -01	1,541E -01	1,560E -01	1,546E -01	1,596E -01	1,550E -01	1,533E -01
5	1,558E -01	1,573E -01	1,573E -01	1,572E -01	1,623E -01	1,569E -01	1,556E -01
6	1,542E -01	1,560E -01	1,565E -01	1,562E -01	1,608E -01	1,558E -01	1,542E -01
Statistics							
Min	1,475E -01	1,512E -01	1,506E -01	1,488E -01	1,531E -01	1,483E -01	1,473E -01
Max	1,560E -01	1,573E -01	1,573E -01	1,573E -01	1,623E -01	1,569E -01	1,556E -01
Mean	1,535E -01	1,549E -01	1,556E -01	1,548E -01	1,593E -01	1,546E -01	1,532E -01
Sigma	3,453E -03	2,413E -03	2,815E -03	3,507E -03	3,612E -03	3,604E -03	3,407E -03

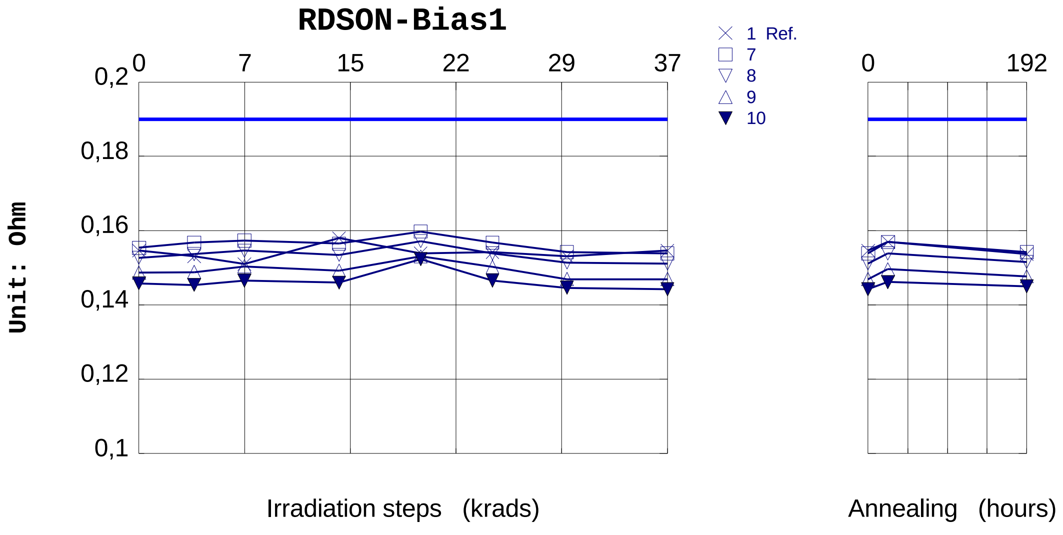
Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	1,546E -01	1,569E -01	1,537E -01
2	1,473E -01	3,438E -01	1,588E -01
3	1,556E -01	1,592E -01	1,714E -01
4	1,535E -01	1,556E -01	1,723E -01
5	1,558E -01	2,789E -01	1,685E -01
6	1,549E -01	2,658E -01	1,645E -01
Statistics			
Min	1,473E -01	1,556E -01	1,588E -01
Max	1,558E -01	3,438E -01	1,723E -01
Mean	1,534E -01	2,407E -01	1,671E -01
Sigma	3,528E -03	8,155E -02	5,536E -03



Parameter: Static drain to source on-state resistance: RDSON-Bias1 **VGS=10V, ID=13,1A**
Unit= Ohm
Spec limit max: 0.1
Spec limits are represented in bold lines on the graphic.

Test Step	Initial	3,85 krads	7,35 krads	13,95 krads	19,65 krads	24,65 krads	29,85 krads
Serial #							
1 Ref.	1,546E -01	1,531E -01	1,510E -01	1,579E -01	1,538E -01	1,542E -01	1,531E -01
7	1,554E -01	1,568E -01	1,573E -01	1,565E -01	1,597E -01	1,568E -01	1,542E -01
8	1,527E -01	1,537E -01	1,546E -01	1,535E -01	1,572E -01	1,538E -01	1,514E -01
9	1,487E -01	1,488E -01	1,504E -01	1,492E -01	1,531E -01	1,502E -01	1,469E -01
10	1,458E -01	1,454E -01	1,465E -01	1,460E -01	1,523E -01	1,465E -01	1,446E -01
Statistics							
Min	1,458E -01	1,454E -01	1,465E -01	1,460E -01	1,523E -01	1,465E -01	1,446E -01
Max	1,554E -01	1,568E -01	1,573E -01	1,565E -01	1,597E -01	1,568E -01	1,542E -01
Mean	1,506E -01	1,512E -01	1,522E -01	1,513E -01	1,556E -01	1,518E -01	1,493E -01
Sigma	4,252E -03	5,057E -03	4,735E -03	4,639E -03	3,495E -03	4,439E -03	4,331E -03

Test Step	36,85 krads	24 hours	192 hours
Serial #			
1 Ref.	1,546E -01	1,569E -01	1,537E -01
7	1,538E -01	1,569E -01	1,542E -01
8	1,512E -01	1,538E -01	1,515E -01
9	1,469E -01	1,496E -01	1,477E -01
10	1,442E -01	1,462E -01	1,450E -01
Statistics			
Min	1,442E -01	1,462E -01	1,450E -01
Max	1,538E -01	1,569E -01	1,542E -01
Mean	1,490E -01	1,516E -01	1,496E -01
Sigma	4,289E -03	4,725E -03	4,082E -03



8 Conclusion

A total dose radiation verification test has been performed on SPPX1N60S5 N-Channel Power Mosfet from Siemens up to 36.85 Krad(Si) accumulated dose.

This device exhibits a dramatic drop in breakdown voltage, after first annealing step under Bias 2 conditions. No significant recovery is observed afterwards.
Gate leakage current has increased (up to the compliance value of 1mA) after 24H annealing, for Bias 2 conditions.

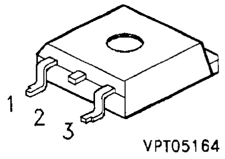
Threshold voltage is out of specification at 13.95 Krad(Si) under Bias 1 conditions, and no recovery occurred after 168 hours annealing step.
Threshold voltage is also out of specification at 13.95 Krad(Si) under Bias 2 conditions, and partial recovery is observed after 168 hours annealing step.

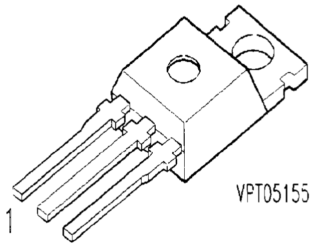
This device has shown a significant susceptibility to radiation induced effects.

ANNEX 1 : SPPX1N60S5 DATA SHEET

Cool MOS™ Power Transistor

- Worldwide best $R_{DS(on)}$ in TO 220
- N-Channel
- Enhancement mode
- Ultra low gate charge
- Avalanche rated
- d*v*/d*t* rated
- 150°C operating temperature





1	2	3
G	D	S

Type	V_{DS}	I_D	$R_{DS(on)}$	Marking	Package	Ordering Code
SPPX1N60S5	600 V	20.7 A	190 mΩ	X1N60S5	P-TO220-3-1	-
SPBX1N60S5					P-TO263-3-2	-

Maximum Ratings, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Value	Unit
Drain source voltage	V_{DSS}	600	V
Continuous drain current	I_D		A
T_C = 25 °C		20.7	
T_C = 100 °C		13.1	
Pulsed drain current T_C = 25 °C	$I_{D\ puls}$	42	
Avalanche energy, single pulse I_D = 20.7 A, V_{DD} = 50 V, R_{GS} = 25 Ω	E_{AS}	690	mJ
Avalanche current (periodic, limited by T_{jmax})	I_{AR}	tbd	A
Avalanche energy (10 kHz, limited by T_{jmax})	E_{AR}	tbd	mJ
Reverse diode d*v*/d*t* I_S = 20.7 A, $V_{DS}<V_{DSS}$, d*i*/d*t* = 100 A/µs, T_{jmax} = 150 °C	d*v*/d*t*	6	KV/µs
Gate source voltage	V_{GS}	±20	V
Power dissipation, T_C = 25 °C	P_{tot}	208	W
Operating temperature	T_j	-55 ...+150	°C
Storage temperature	T_{stg}	-55 ... +150	
IEC climatic category; DIN IEC 68-1		55/150/56	

Electrical Characteristics

Parameter at T_j = 25 °C, unless otherwise specified	Symbol	Values			Unit
		min.	typ.	max.	
Thermal Characteristics					
Thermal resistance, junction - case	R_{thJC}	-	-	0.6	K/W
Thermal resistance, junction - ambient (Leaded and through-hole packages)	R_{thJA}	-	62	-	
SMD version, device on PCB:	R_{thJA}				
@ min. footprint		-	tbd	-	
@ 6 cm^2 cooling area 1)		-	35	-	

Static Characteristics

Drain- source breakdown voltage V_{GS} = 0 V, I_D = 0.25 mA	$V_{(BR)DSS}$	600	-	-	V
Gate threshold voltage, V_{GS} = V_{DS}	$V_{GS(th)}$				
I_D = 1 mA, T_j = 25 °C		3.5	4.5	5.5	
I_D = 1 mA, T_j = 150 °C		tbd	-	-	
Zero gate voltage drain current, V_{DS}=V_{DSS}	I_{DSS}				µA
V_{GS} = 0 V, T_j = -40 °C		-	-	0.1	
V_{GS} = 0 V, T_j = 25 °C		-	0.5	1	
V_{GS} = 0 V, T_j = 150 °C		-	-	tbd	
Gate-source leakage current V_{GS} = 20 V, V_{DS} = 0 V	I_{GSS}	-	10	100	nA
Drain-Source on-state resistance V_{GS} = 10 V, I_D = 13.1 A	$R_{DS(on)}$	-	tbd	190	mΩ

---

[1] Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6 cm2 (one layer, 70µm thick) copper area for drain connection. PCB is vertical without blown air.

Electrical Characteristics

Parameter at T_j = 25 °C, unless otherwise specified	Symbol	Values			Unit
		min.	typ.	max.	
Characteristics					
Transconductance $V_{DS} \geq 2 * I_D * R_{DS(on)max}$, I_D = 13.1 A	g_{fs}	-	tbd	-	S
Input capacitance V_{GS} = 0 V, V_{DS} = 25 V, f = 1 MHz	C_{iss}	-	3000	tbd	pF
Output capacitance V_{GS} = 0 V, V_{DS} = 25 V, f = 1 MHz	C_{oss}	-	1900	tbd	
Reverse transfer capacitance V_{GS} = 0 V, V_{DS} = 25 V, f = 1 MHz	C_{rss}	-	100	tbd	
Turn-on delay time V_{DD} = 350 V, V_{GS} = 10 V, I_D = 20.7 A	$t_{d(on)}$	-	tbd	tbd	ns
Rise time V_{DD} = 350 V, V_{GS} = 10 V, I_D = 20.7 A, R_G = 3.6 Ω	t_r	-	tbd	-	
Turn-off delay time V_{DD} = 350 V, V_{GS} = 10 V, I_D = 20.7 A, R_G = 3.6 Ω	$t_{d(off)}$	-	tbd	tbd	
Fall time V_{DD} = 350 V, V_{GS} = 10 V, I_D = 20.7 A, R_G = 3.6 Ω	t_f	-	tbd	-	

Electrical Characteristics

Parameter at T_j = 25 °C, unless otherwise specified	Symbol	Values			Unit
		min.	typ.	max.	
Gate Charge Characteristics					
Gate-source charge I_D = 20.7 A, V_{DD} = 400 V	Q_{gs}	-	tbd	-	nC
Gate-drain charge I_D = 20.7 A, V_{DD} = 400 V	Q_{gd}	-	tbd	-	
Total gate charge V_{DD} = 400 V, I_D = 20.7 A, V_{GS} = 0 to 10 V	Q_G	-	100	tbd	

Reverse Diode

Continuous source current T_C = 25 °C	I_S	-	-	20.7	A
Pulsed source current T_C = 25 °C	I_{SM}	-	-	42	
Inverse diode forward voltage V_{GS} = 0 V, I_F = 20.7 A	V_{SD}	-	tbd	1.2	V
Reverse recovery time V_R = 100 V, I_F=I_S , di_F/dt = 100 A/µs	t_{rr}	-	tbd	-	ns
Reverse recovery charge V_R = 100 V, I_F=I_S , di_F/dt = 100 A/µs	Q_{rr}	-	4.5	-	µC

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Errata sheet to target data sheetSPPX1N60S5:

Samples with datecode $\leq$ 830:

- Reduced avalanche rating
- Reverse diode $dv/dt \leq$ 4 KV/µs
- Gate threshold voltage $V_{GS(th)}$: upper limit 6V