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DOCUMENT

RA0567 CO60 TID Test Results on Part Type 2N5115

RA_0597_2N5115

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APPROVAL

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Issue 1	**Revision** 0
Author: Michele Muschitiello TEC-QEC	**Date 18 April 2012**
Approved by	**Date**
Cesar Boatella Polo TEC-QEC	**19 April 2012**
Authorised by	**Date**
Ali Zadeh TEC-QEC HoS	**20 April 2012**

CHANGE LOG

Reason for change	Issue	Revision	Date
issued for first release	1	0	20 April 2012

CHANGE RECORD

Issue 1	**Revision** 0		
Reason for change	**Date**	**Pages**	**Paragraph(s)**

Table of contents:

1 ACRONYMS

TID Total Irradiation Dose

2 REFERENCES

REF1 ESA/SCC 22900 “Total Dose Steady-State Irradiation Test Method”, issue 3

3 PURPOSE

The purpose of this test report is to describe the TID test performed according to REF1 on the devices below specified.

4 SCOPE

This documents reports the test results obtained on silicon Field Effect Transistor, P-Channel, based on part type 2N2515, Part Number JANTXV2N5115 and Date Code 0746 to be used in the frame of MeteoSat 2nd Generation, ESA Project MSG-03 (MSG-UGS).

5 TEST DESCRIPTION

5.1 Facility and Dosimetry

The ESTEC Co-60 facility comprises of a Nordion Gammabeam 150C irradiator containing a nominal 84 TBq (2200 Ci) Co-60 source at the last reload date in October 2011. The irradiation room is monitored for temperature, relative humidity and pressure.

The dosimetry system is based on Farmer type 2571A 0.6 cc air ionisation chambers linked to Farmer 2670 electrometers. The dosimetry system is compensated against temperature and pressure environmental fluctuation.

All irradiations and measurements were performed at room temperature (22.5 ± 3 °C).

5.2 Devices Under Test

A total of ten serialised devices were received from the Project.

Part description:

Component Designation	2N5115
Manufacturer	Solitron
Family	Field Effect Transistor
Group	Silicon
Package	TO-18
Component Specification	MIL-PRF-19500/476E
Part Identification Number	JV2N5115 F07-83 1 0746
Lot date code	0746
Device serial numbers	from s/n 27 to s/n 36.

The devices from s/n 27 to s/n 30 were irradiated with bias applied according to the schematic in Figure 1.

The devices from s/n 31 to 34 were irradiated with all the pins grounded (un-biased).

Table 1 summarize the sample usage.

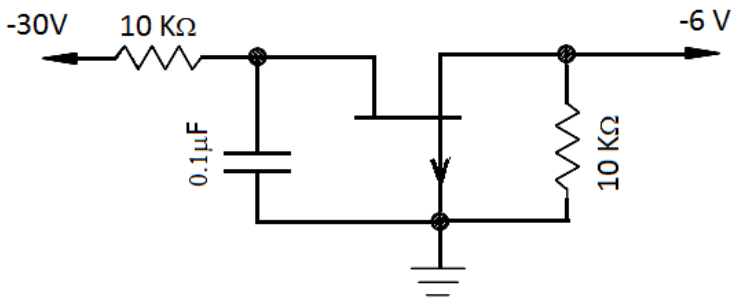


Figure 1 Biasing circuit

Table 1 received samples and their usage.

S/n's	Description
27, 28, 29, 30	Biased during ^{60}Co irradiation
31, 32, 33, 34	Unbiased during ^{60}Co irradiation
35, 36	Reference devices (not irradiated) - Electrically tested before and after each intermediate measurement run at irradiation step completion

5.3 Radiation Test Plan

The actual radiation test steps are reported in Table 2.

Table 2 Irradiation Test Plan

Step	Total Dose (Si) krad	Dose Rate (Si)rad/min
(Pre irradiation) 0	==	==
Irradiation step # 1	2.00	0.61
Irradiation step # 2	7.00	0.59
Irradiation step # 3	15.00	0.60

At the completion of each irradiation step, intermediate electrical measurements were carried out according to the next paragraph.
At the end of the final irradiation run, all devices were electrically measured and annealed for 24 hours at room temperature and subsequently aged at 100°C (for 286 hrs in total), maintaining the same bias conditions applied during the TID test.
Table 3 reports the annealing/aging sequence detail.

Table 3 Anneal/aging sequence

Step	Temperature	Duration
Anneal	Room temperature	24 hours
Aging	100 °C	286 hours

At the completion of each anneal/aging step, all devices were electrically tested.

5.4 Measurement Set-up

No in-situ measurements were performed during irradiation. The measured parameters and the adopted min-max limits (pass/fail criteria) are listed in Table 4.

Table 4 Measured Parameters, Min-Max Limits

nr.	Parameter ID	Parameter description	Test conditions	Limits		Unit
				Min.	Max.	
1	$I_{D(off)1}$	Drain cut off current	V_{DS}=-15V, V_{GS}= 7V	-500		pA
2	I_{DSS}	Zero gate voltage Drain current	V_{DS}=-15V, V_{GS}= 0V	-60	-15	mA
3	$V_{(BR)GSS}$	Gate to Source breakdown	V_{DS}= 0V, I_{GS}= 1.0µA	30		V
4	I_{GSS}	Gate reverse current	V_{GS}= 20V		500	pA
5	$r_{ds(on)1}$	Drain to Source on resistance	V_{GS}= 0V, I_D= -1.0mA		100	Ohm
6	$V_{DS(on)}$	Drain to Source ON voltage	I_{DS}=-7mA, V_{GS}= 0V	-0.8		V
7	$V_{GS(off)}$	Gate to Source cut off voltage	V_{DS}=-15V, I_D= -1nA	3	6	V

All the above parameters have been measured by using the following equipment:

Test Equipment: AGILENT model 4156C s/n JP10J00469
Test Fixture: AGILENT model 16442A s/n JP10A02054

Last valid calibration date: Dec 2011

The electrical parameters were tested according to MIL-PRF-19500/467E, Table I, Subgroup 2.

6 TEST RESULTS

All measurement results are reported from Table 5 to Table 11. Test ended with a registered Total Dose of 15 krad(Si).
At the end of the last irradiation step, electrical measurements were performed. The devices were tested again after 24 hours annealing at room temperature.
After the annealing, the samples went through 286 hours at 100°C accelerated ageing and were measured afterward to verify parameter drift time dependency.
During the entire annealing/aging, the irradiated devices were biased employing the same test board.

Electrical Measurement uncertainty values, reported in the relevant table header, were estimated by combining the instrument uncertainty for the measured parameter according to the specification of the Test Equipment and the variations of the same parameter in the reference device (s/n), observed during the entire test campaign.

Significant data from tables have also been plotted from Figure 2 to Figure 8.

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
biased	27	-5.2	-11.6	-10.8	-66.1	-46.4	-6.6
	28	-7.1	-12.8	-12.4	-73.5	-49.5	-9.6
	29	-5.2	-10.6	-9.3	-69.5	-49.6	-8.5
	30	-4.9	-10.8	-9.6	-60.6	-44.7	-5.7
Unbiase	31	-9.2	-11.6	-9.4	-26.2	-18.3	-13.8
	32	-4.6	-9.3	-7.3	-24.9	-17.5	-11.9
	33	-4.7	-8.7	-6.7	-23.6	-16.0	-11.6
	34	-5.1	-8.7	-6.6	-25.6	-15.9	-11.8
ref	35	-4.8	-9.3	-4.2	-14.4	-7.2	-6.7
	36	-4.0	-8.6	-3.6	-13.3	-6.5	-6.2

Table 5: $I_{D(off)}1$ - Drain cut off current [pA]

Limits:	min	max	
	-500		pA

Expanded uncertainty (k=2):	7 pA

Note: All values were within the limits. Biased devices showed slightly higher radiation sensitivity.

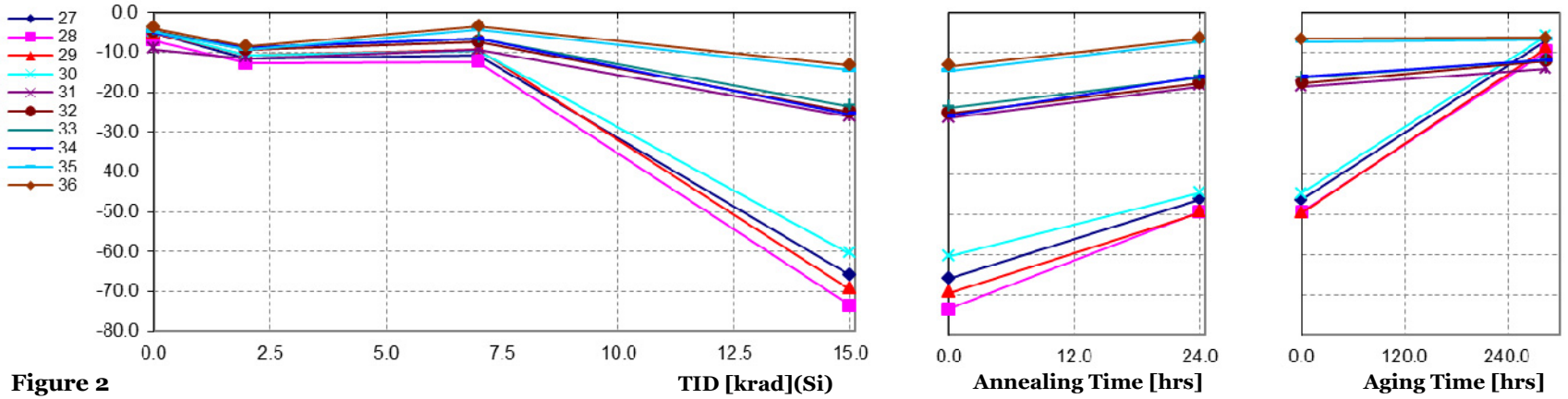


Figure 2

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
biased	27	-30.0	-31.0	-31.0	-30.7	-31.0	-30.9
	28	-29.5	-30.4	-30.4	-30.0	-30.3	-30.3
	29	-26.5	-27.3	-27.3	-26.6	-27.1	-27.1
	30	-25.1	-25.8	-25.9	-25.5	-25.9	-25.7
Unbiase	31	-23.9	-24.7	-24.7	-24.3	-24.6	-24.7
	32	-34.8	-35.8	-35.8	-34.9	-35.7	-35.7
	33	-33.5	-34.5	-34.5	-34.1	-34.5	-34.6
	34	-23.9	-24.6	-24.6	-24.3	-24.5	-24.6
ref	35	-24.1	-24.8	-24.9	-24.5	-24.9	-24.9
	36	-34.6	-35.7	-35.8	-35.2	-35.6	-35.8

Table 6: I_{DSS} - Zero gate voltage Drain current [mA]

Limits:	min	max	
	-60	-15	mA

Expanded uncertainty (k=2):	0.5 mA

Note: All values were within the limits.

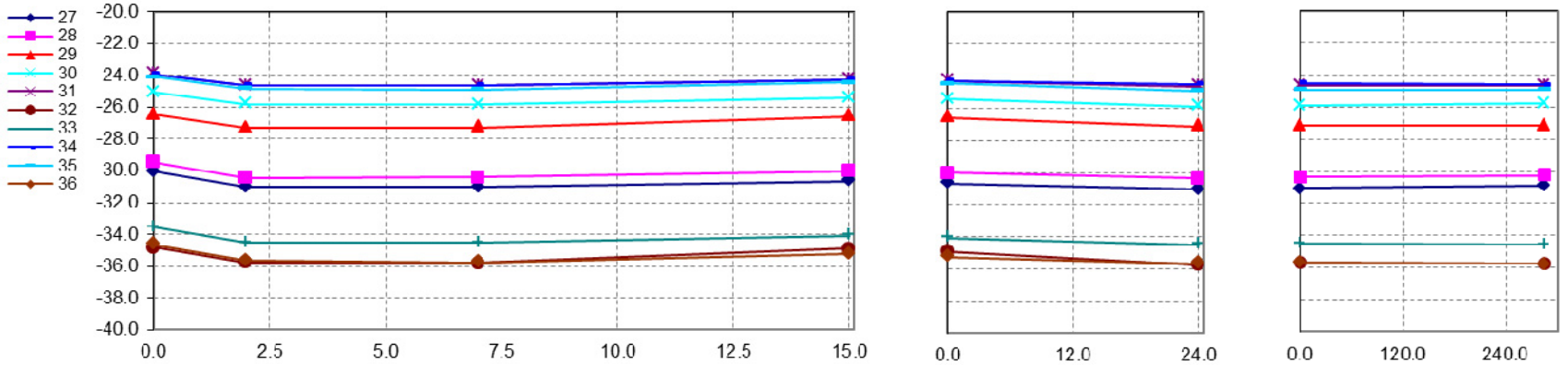


Figure 3

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
biased	27	68.78	69.62	70.96	71.89	71.75	71.26
	28	36.75	36.76	36.76	36.75	36.76	36.60
	29	69.17	70.12	71.35	72.25	72.14	71.65
	30	68.86	69.67	70.96	71.93	71.69	71.17
Unbiase	31	69.03	69.97	71.05	72.40	72.16	71.50
	32	67.12	69.29	70.37	71.53	71.33	70.65
	33	68.45	69.23	70.34	71.49	71.30	70.57
	34	69.04	69.79	70.91	72.12	71.87	71.15
ref	35	69.30	69.18	69.04	69.16	69.05	69.04
	36	68.66	68.53	68.40	68.50	68.44	68.40

Table 7: $V_{(BR)GSS}$ - Gate to Source breakdown [V]

Limits:	min	max	
	30		V

Expanded uncertainty (k=2):	0.2 V

Note: All values were within the limits. Data have been plotted as relative % change respect to the initial value since device s/n 28 exhibits, on average, lower values with respect to the other parts.

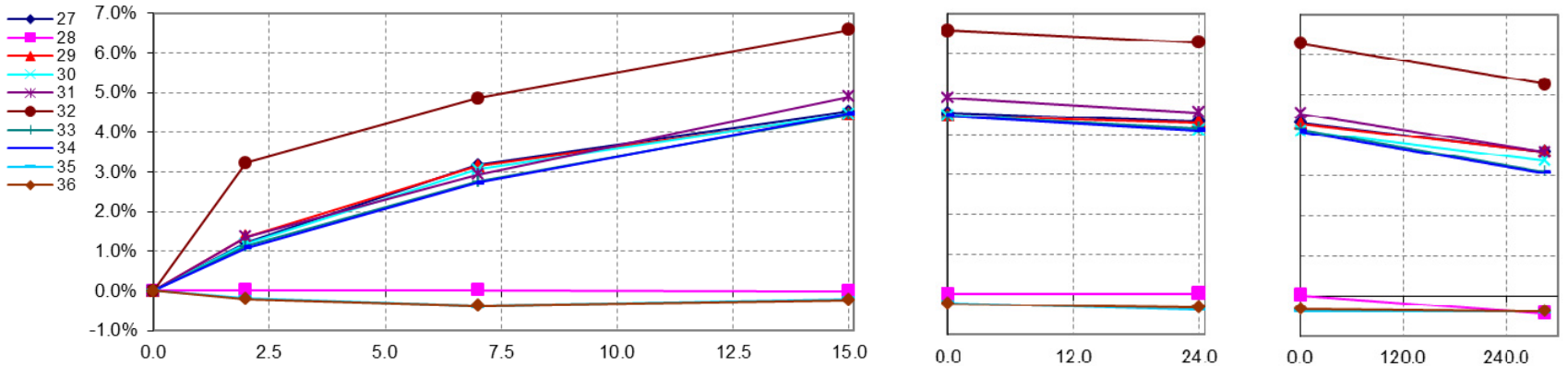


Figure 4

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
biased	27	18.2	42.2	78.4	199.4	174.3	72.6
	28	24.1	44.9	74.6	196.4	149.2	73.6
	29	17.1	41.1	83.9	266.2	210.9	70.5
	30	15.1	40.4	76.6	217.5	160.6	70.9
Unbiase	31	42.0	57.2	93.9	235.9	205.2	131.0
	32	17.7	43.7	85.7	247.3	201.5	120.2
	33	16.5	42.3	86.5	244.4	201.1	121.2
	34	15.6	38.5	78.6	232.6	194.6	114.1
ref	35	19.3	29.3	17.9	35.7	23.9	22.3
	36	17.4	27.5	16.5	34.2	22.6	21.6

Table 8: I_{GSS} - Gate reverse current [pA]

Limits:	min	max	
		500	pA

Expanded uncertainty (k=2):	9 pA

Note: All values were within the limits.

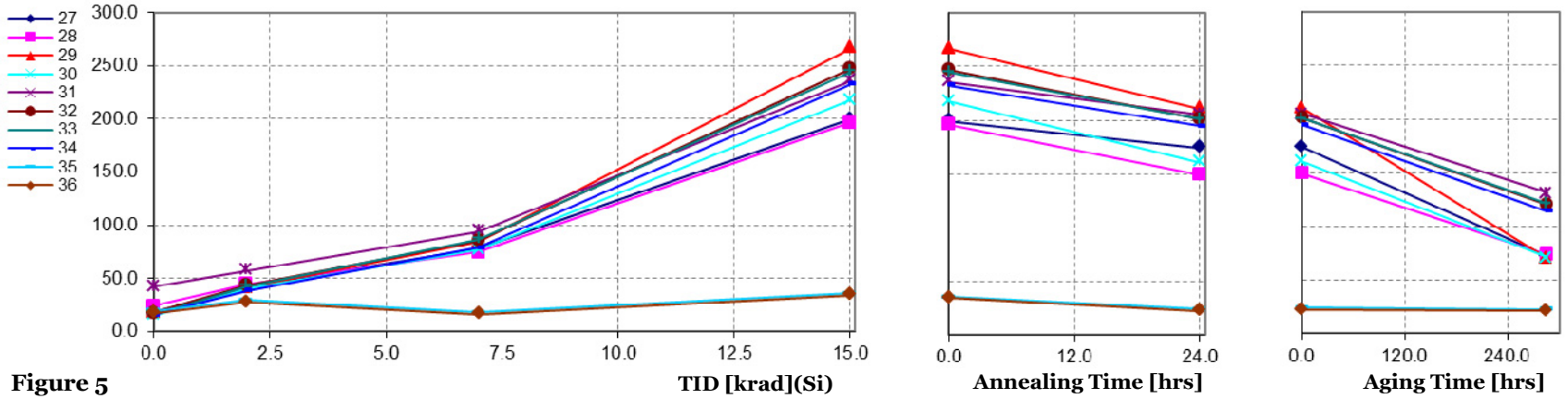


Figure 5

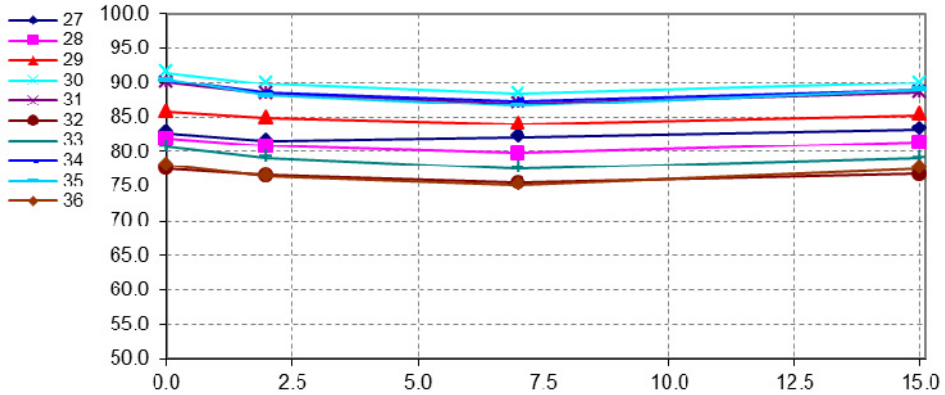
		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
biased	27	82.7	81.5	82.1	83.2	81.6	82.3
	28	81.8	80.8	79.7	81.3	80.2	80.6
	29	85.7	84.8	83.9	85.3	83.9	84.6
	30	91.4	89.9	88.3	89.9	88.5	89.5
Unbiase	31	89.9	88.3	86.9	88.5	86.9	87.0
	32	77.6	76.6	75.6	76.8	75.6	75.4
	33	80.7	79.1	77.5	79.1	77.7	77.7
	34	90.4	88.5	87.3	88.9	87.7	87.2
ref	35	90.4	88.1	86.7	89.0	86.9	86.5
	36	78.0	76.4	75.2	77.6	75.0	75.1

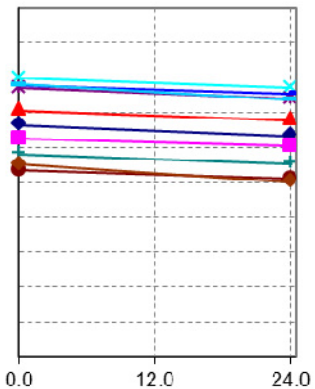
Table 9: $r_{ds(on)1}$ - Drain to Source on resistance [Ohm]

Limits:	min	max	
		100	Ohm

Expanded uncertainty (k=2):	2 Ohm

Note: All values were within the limits.





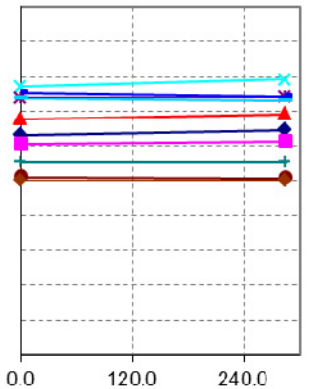


Figure 6

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
biased	27	-0.62	-0.61	-0.61	-0.63	-0.61	-0.62
	28	-0.62	-0.60	-0.60	-0.61	-0.60	-0.61
	29	-0.66	-0.63	-0.63	-0.65	-0.64	-0.64
	30	-0.70	-0.67	-0.67	-0.69	-0.67	-0.68
Unbiase	31	-0.69	-0.66	-0.66	-0.68	-0.67	-0.67
	32	-0.58	-0.56	-0.56	-0.57	-0.56	-0.56
	33	-0.60	-0.58	-0.57	-0.59	-0.58	-0.58
	34	-0.70	-0.67	-0.66	-0.68	-0.67	-0.67
ref	35	-0.70	-0.66	-0.66	-0.68	-0.66	-0.66
	36	-0.59	-0.56	-0.56	-0.57	-0.56	-0.56

Table 10: $V_{DS(on)}$ - Drain to Source ON voltage [V]

Limits:	min	max	
	-0.8		V

Expanded uncertainty (k=2):	0.03 V

Note: All values were within the limits.

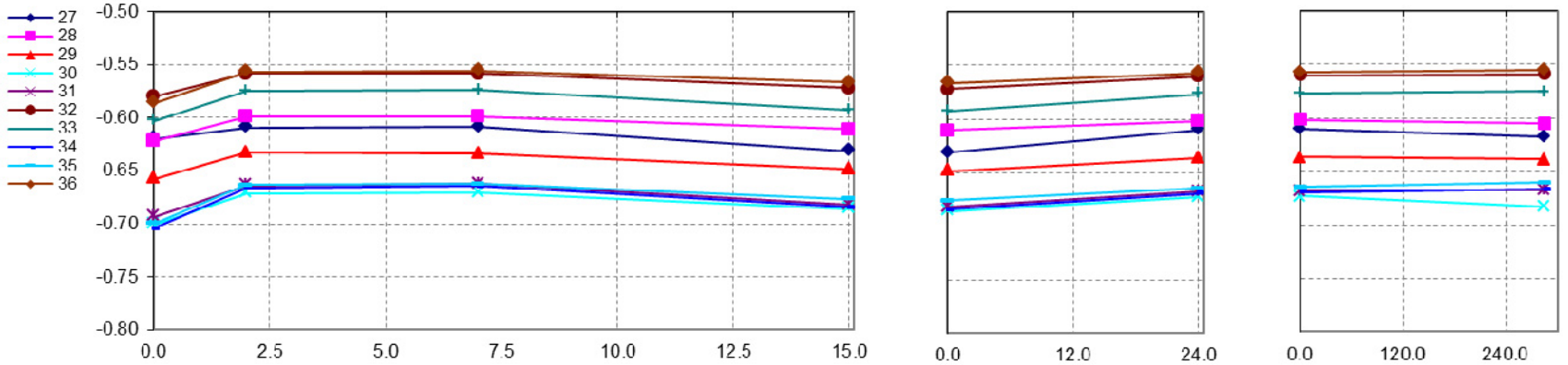


Figure 7

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
biased	27	4.28	4.27	4.27	4.27	4.27	4.26
	28	4.23	4.22	4.22	4.22	4.21	4.21
	29	3.84	3.83	3.83	3.84	3.83	3.83
	30	3.76	3.75	3.75	3.75	3.75	3.75
Unbiase	31	3.58	3.57	3.57	3.58	3.57	3.57
	32	4.72	4.71	4.71	4.72	4.71	4.71
	33	4.62	4.62	4.61	4.62	4.61	4.61
	34	3.58	3.58	3.58	3.58	3.58	3.58
ref	35	3.59	3.59	3.58	3.58	3.58	3.58
	36	4.80	4.80	4.79	4.79	4.79	4.79

Table 11: $V_{GS(off)}$ - Gate to Source cut off voltage [V]

Limits:	min	max	
	3	6	V

Expanded uncertainty (k=2):	0.03 V

Note: All values were within the limits.

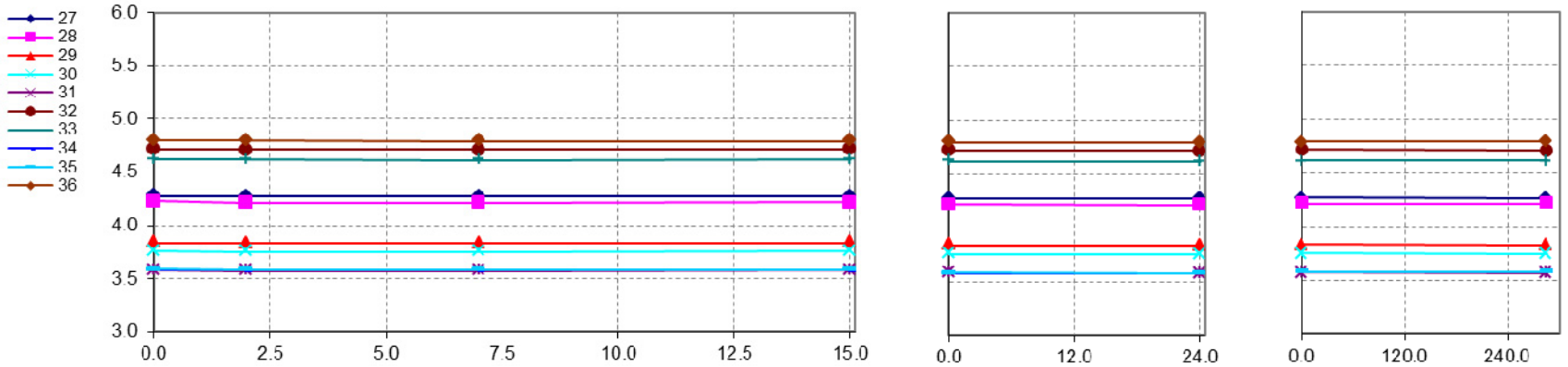


Figure 8

7 SUMMARY OF RESULT AND CONCLUSION

No catastrophic failures nor parametric out of specs were observed during the entire test up to 15krad(Si) TID. The irradiation test results are summarized in Table 12.

Table 12 Summary of TID test results

nr.	Parameter	Remarks	Worst Case Bias Condition	Data in	
1	$I_{D(off)1}$	TID induced degradation . Evidence of Bias condition dependence. All devices still within the limits.	Biased	Table 5	Figure 2
2	I_{DSS}	No evidence of TID dependent degradation. All devices still within the limits.	none	Table 6	Figure 3
3	$V_{(BR)GSS}$	TID induced degradation showing an increase up to +7%. No evidence of Bias condition dependence. Device s/n 28 exhibits, an average values that are about half of the remaining parts (36V against 69V). All devices still within the limits.	none	Table 7	Figure 4
4	I_{GSS}	TID induced degradation. No evidence of Bias condition dependence. All devices still within the limits. Degradation trends suggest this as the most sensitive parameter.	none	Table 8	Figure 5
5	$r_{ds(on)1}$	No evidence of TID dependent degradation. All devices still within the limits.	none	Table 9	Figure 6
6	$V_{DS(on)}$	No evidence of TID dependent degradation. All devices still within the limits.	none	Table 10	Figure 7
7	$V_{GS(off)}$	No evidence of TID dependent degradation. All devices still within the limits.	none	Table 11	Figure 8

Parameter I_{GSS} data, see Table 13 , have been used for the statistical worst case estimation.
The TID sensitivity was not significantly dependent on BIAS therefore data from all irradiated devices were used for the statistical analysis.
The resulting estimation is graphically reported in Figure 9.
The horizontal error bars represent the dosimetry uncertainty as stated in the relevant radiation summary (Appendix A)
The statistical part to part uncertainty (vertical bars) is calculated from Table 13 by applying the coverage factor k=2.37 as applicable to the 7 degrees of freedom (8 observations-1) for the 95% confidence level.

Table 13: I_{GSS} - Gate reverse current [pA].

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
ref	35	19.3	29.3	17.9	35.7	23.9	22.3
	36	17.4	27.5	16.5	34.2	22.6	21.6
Irradiated devices	27	18.2	42.2	78.4	199.4	174.3	72.6
	28	24.1	44.9	74.6	196.4	149.2	73.6
	29	17.1	41.1	83.9	266.2	210.9	70.5
	30	15.1	40.4	76.6	217.5	160.6	70.9
	31	42.0	57.2	93.9	235.9	205.2	131.0
	32	17.7	43.7	85.7	247.3	201.5	120.2
	33	16.5	42.3	86.5	244.4	201.1	121.2
	34	15.6	38.5	78.6	232.6	194.6	114.1
	Min	15.1	38.5	74.6	196.4	149.2	70.5
	Max	42.0	57.2	93.9	266.2	210.9	131.0
	Average	20.8	43.8	82.3	229.9	187.2	96.8
	Std.Dev.	9.0	5.8	6.4	24.1	22.8	27.0

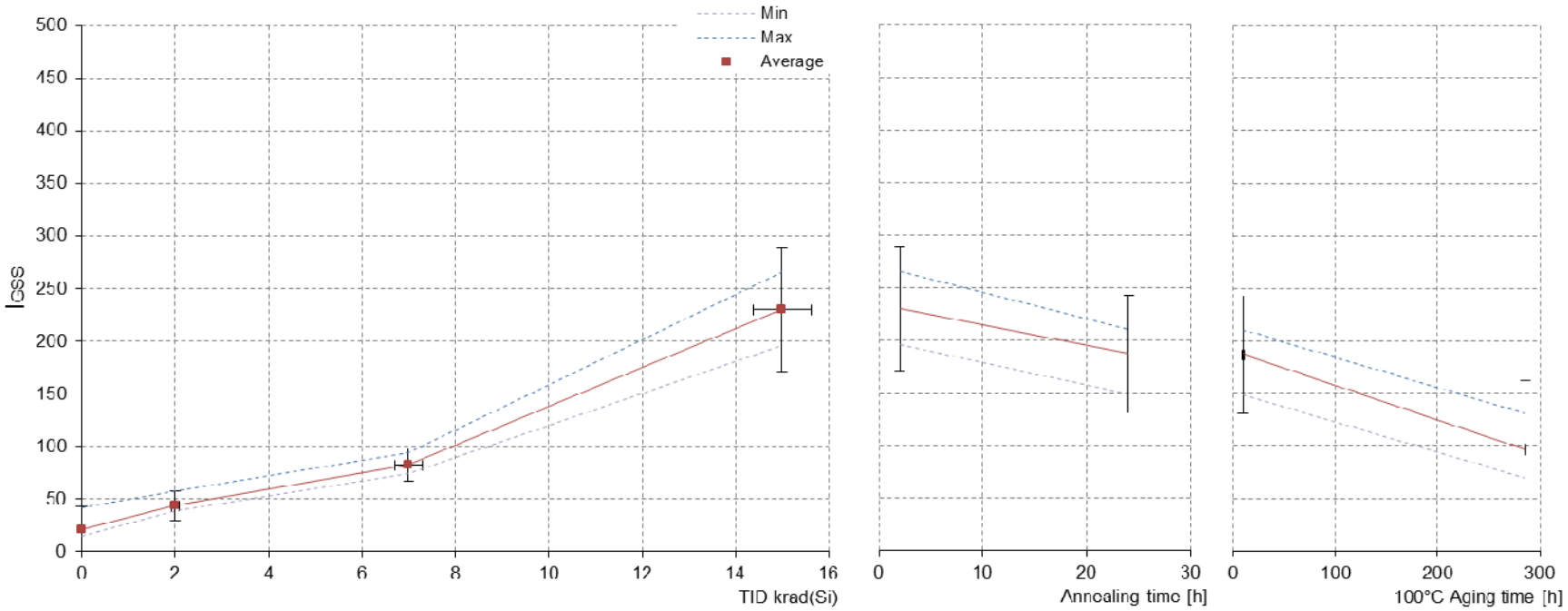

Min
Max
Average
Iccs
500
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
TID krad(Si)
0
10
20
30
Annealing time [h]
0
100
200
300
100°C Aging time [h]

Figure 9

APPENDIX A RADIATION SUMMARY NR 20161

ESTEC ^{60}Co Facility

Keplerlaan, 1 2200AG Noordwijk ZH (NL)

RADIATION TEST SUMMARY

Irradiation Test Report Number : 20161 *Date :* 18 April 2011

Test Requester :	*Name*	ESA ESTEC TEC-QEC
	Address	Keplerlaan, 1 2200AG Noordwijk ZH (NL)
	Personnel present :	Cesar Boatella Polo
	Project/Cost Code :	MSG 2
	Devices/Components irradiated :	JANS2N2484 s/n's: 981, 982, 991, 1000, 1001, 1004, 1013, 1026 JANTXV2N5115 s/n's: 27, 28, 29, 30, 31, 32, 33, 34
	Device/Component details : (conditions and identification)	See radiation test report nr RA0596 (for the 2N2484) and RA0597 (for the 2N5115)
	Dosimetry Chain used :	A
	Dosimeter :	Farmer model 2680 – s/n 390
	Gas Ionisation Chamber :	NE Type 2571 – s/n 2915
	Measured Dosimetry :	Total Ionising Dose in [Gy] (water)
	Dosimetry Procedure :	ESCC 22900 section 4.1.1 TEC-QEC/PR001 - Appendix D

(With the exception of the above specified dosimetry equipment, ESTEC ^{60}Co Facility does not assume any liability for the calibration status of any other equipment lent to the requester)

Irradiation Test Campaign Details

Source Activity : 78.46 TBq *on date :* 03/04/2012

	units	Min.	Max.	Time-weighted Average
Temperature	°C	24.8	24.9	24.89
Pressure	mbar	1000.0	1018.1	1007.54
Relative Humidity	%	30.4	32.6	31.60

Dosimeter position relative to ^{60}Co source		
X	cm	-15
Y	cm	230
Z	cm	20

Run	Start Date & Time (CET)	End Date & Time (CET)	Total Ionising Dose [Gy] (water)	Dose Rate [Gy/h] (water)
1	03 Apr 2011 18:09:35	03 Apr 2011 19:59:56	22.27	3.96
2	03 Apr 2011 13:25:53	04 Apr 2011 11:04:12	55.68	3.94
3	04 Apr 2011 13:15:30	05 Apr 2011 10:31:41	89.09	3.93

Note: The uncertainty budgets (according to TEC-QEC/PR001 section 12) are: 4.2 % (k=2) for absorbed dose to water and 4.4% (k=2) for absorbed dose rate to water.

Michele Muschitiello
(TEC-QEC Radiation Test Engineer)

Ali Zadeh
(TEC-QEC Section Head)