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DOCUMENT

RA0596 CO60 TID Test Results on Part Type 2N2484

RA_0596_2N2484

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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

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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 ESCC 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 Low Power NPN Transistor, based on part type 2N2484, Part Number JANS2N2484UB and Date Code 0741 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.

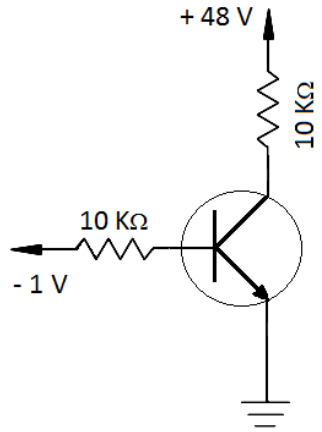
All irradiations and measurements were performed at room temperature (22.5 ± 3 °C).

5.2 Devices Under Test

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

Part description:

Component Designation	2N2484
Manufacturer	SEMICOA
Family	Low Power NPN Transistor
Group	Silicon
Package	Chip Carrier Package – 4 terminals
Component Specification	ESCC 5201/001
Part Identification Number	JS2N2484 SC 0741
Lot date code	0741
Device serial numbers	969, 971, 981, 982, 991, 1000, 1001, 1004, 1013, 1026



The devices s/n's 981, 982, 991 and 1000 were irradiated with bias applied according to the schematic in Figure 1.

The devices s/n's 1001, 1004, 1013 and 1026 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
969, 971	Reference devices (not irradiated) - Electrically tested before and after each intermediate measurement run at irradiation step completion
981, 982, 991, 1000	Biased during ^{60}Co irradiation
1001, 1004, 1013, 1026	Unbiased during ^{60}Co irradiation

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	$V_{(BR)CBO}$	Collector-Base breakdown voltage	I_C = 10 µA	60		V
2	$V_{(BR)CEO}$	Collector-Emitter breakdown voltage	I_C = 10 mA	60		V
3	$V_{(BR)EBO}$	Emitter-Base breakdown voltage	I_E = 10 µA	6000		mV
4	I_{CBO}	Collector-Base cut off current	V_{CB} = 45 V		10000	pA
5	I_{EBO}	Emitter-Base cut off current	V_{EB} = 5 V		10000	pA
6	$V_{CE(SAT)}$	Collector-Emitter saturation voltage	I_C = 1 mA; I_B = 0.1 mA		350	mV
7	h_{FE4}	Forward Current Transfer Ratio	V_{CE} = 5 V; I_C = 1 mA	250	650	-
8	h_{FE5}	Forward Current Transfer Ratio	V_{CE} = 5 V; I_C = 10 mA		800	-

The parameters nr.4 (I_{CBO}) and 5 (I_{EBO}) 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 remaining parameters have been measured by using the following equipment:

Automatic Test Equipment: model Unimet M3000 s/n 0639001.
Front Test Adapter: model TA07B.1 s/n 994914
Test Adapter: model TA07B s/n 994942
Test Board: TLC-PCB-EM-187
Test Program: 2N2484 SMD[SCC 5201-001 5B] VAR 01,02,03,04,05
Version: 06/01 RISI

Last valid calibration date: August 2011

The electrical parameters were tested according to ESCC5201/001 sub 2.4.1, as applicable.

The parameters in Table 5 were not measurable with the UNIMET M3000 due to the limited resolution and accuracy achievable on the I_B Base and I_C Collector currents. Those parameters were not tested by using the AGILENT 4156C as well because the time required for the intermediate electrical test was not compatible with the ESA ESCC 22900 requirements.

Table 5 Parameters not measurable with the UNIMET M3000

a	**h_{FE1}**	**Forward Current Transfer Ratio**	**V_{CE} = 5 V; I_C = 1 µA**	**30**		**-**
b	**h_{FE2}**	**Forward Current Transfer Ratio**	**V_{CE} = 5 V; I_C = 10 µA**	**100**	**500**	**-**
c	**h_{FE3}**	**Forward Current Transfer Ratio**	**V_{CE} = 5 V; I_C = 100 µA**	**175**	**550**	**-**

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 aging 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
ref	969	205.8	204.1	204.3	204.3	204.8	205.3
	971	205.2	205.0	204.8	204.9	205.3	205.2
biased	981	205.9	205.1	215.7	227.8	229.5	228.8
	982	206.6	205.3	215.4	229.0	231.3	224.7
	991	208.9	206.4	215.1	227.4	229.7	234.3
	1000	208.5	207.2	216.5	228.7	231.1	229.9
Unbiase	1001	209.3	206.4	209.0	212.3	213.5	217.5
	1004	208.3	205.8	208.0	211.3	212.7	216.7
	1013	222.6	218.8	220.2	212.1	224.0	228.3
	1026	209.0	206.6	209.0	222.5	213.2	216.9

Table 6: $V_{(BR)CBO}$ - Collecto

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Expanded un

Note: All values were wi

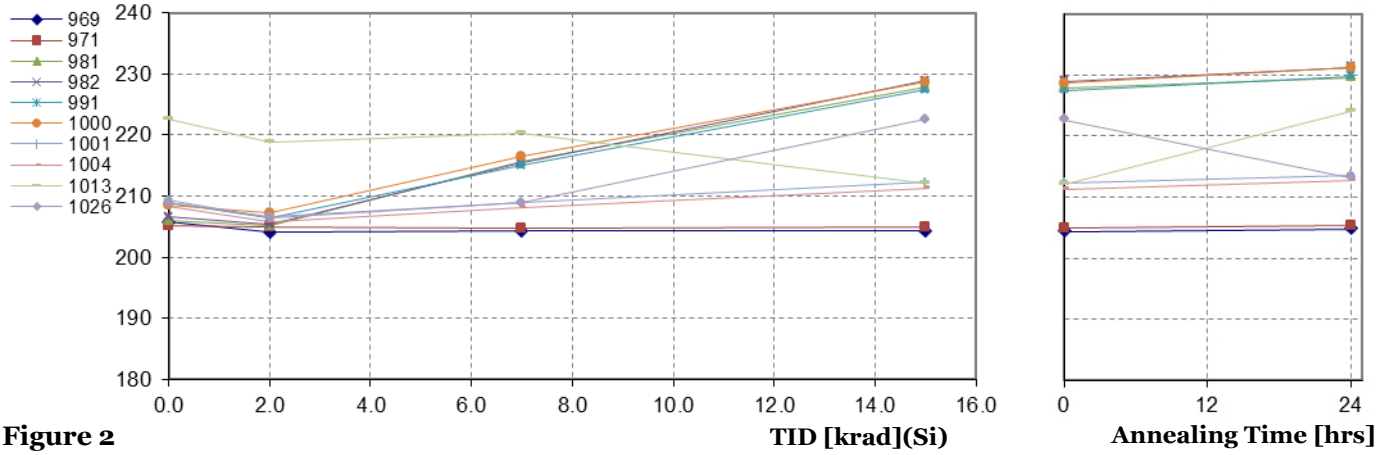

Figure 2

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
ref	969	94.7	93.8	94.0	93.7	93.9	94.1
	971	94.0	93.6	93.7	93.5	93.7	93.7
biased	981	94.8	94.6	95.7	96.5	96.9	96.2
	982	94.5	94.3	95.2	96.3	96.4	97.1
	991	94.4	94.5	95.4	96.7	96.9	95.7
	1000	93.9	94.1	94.6	96.0	96.5	95.7
Unbiase	1001	93.8	93.7	94.8	96.1	96.3	95.3
	1004	94.1	93.9	95.1	96.4	96.5	95.2
	1013	95.0	95.2	96.3	95.7	97.9	96.5
	1026	93.9	94.0	94.5	97.6	96.2	95.1

Table 7: $V_{(BR)CEO}$ - Collector-Emitter breakdown voltage

Limits:	min	max	
	60		V

Expanded uncertainty (k=2):	0.45 V

Note: All values were within the limits.

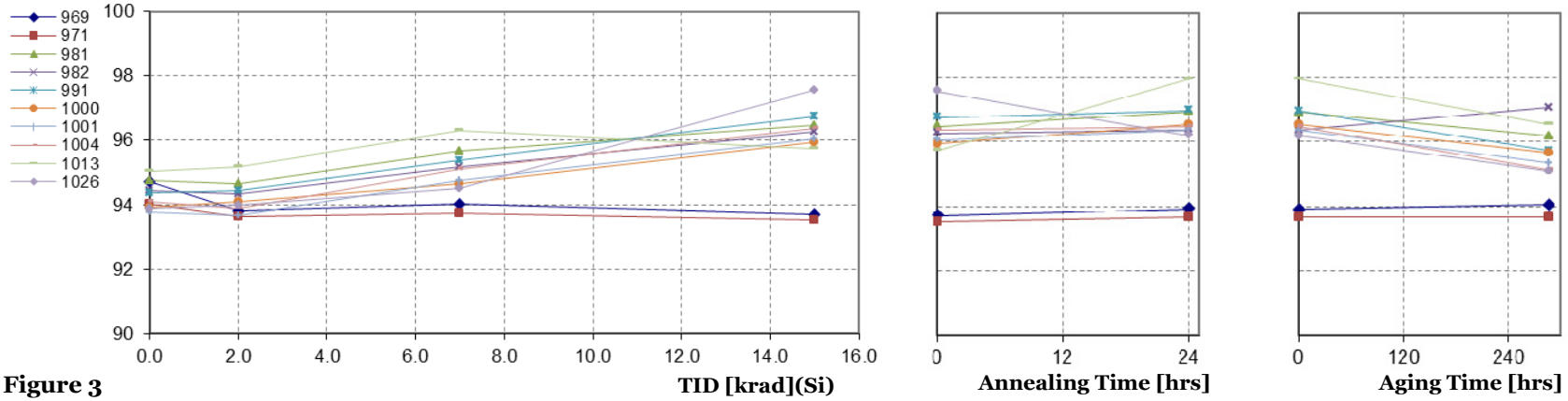

Figure 3

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
ref	969	11117	11152	11048	11062	11101	11033
	971	11169	11073	11031	11030	11170	11036
biased	981	10932	10836	10943	10924	10958	10936
	982	11015	10957	10931	10952	10929	10964
	991	10977	10915	10993	10921	10979	10961
	1000	11335	11240	11234	11223	11255	11260
Unbiase	1001	11278	11262	11228	11203	11263	11343
	1004	11372	11258	11283	11232	11248	11280
	1013	11369	11171	11233	11206	11199	11159
	1026	11320	11171	11201	11089	11201	11233

Table 8: $V_{(BR)EBO}$ - Emitter-Base breakdown voltage

Limits:	min	max	
	6000		mV

Expanded uncertainty (k=2):	180 mV

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

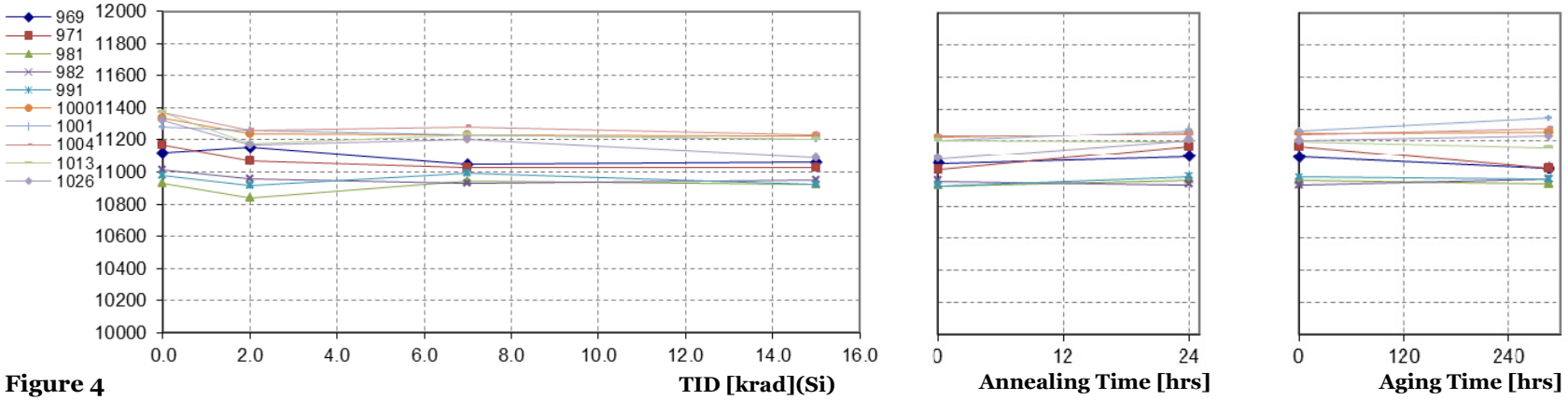

Figure 4

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
ref	969	28	16	29	29	44	121
	971	27	29	46	46	62	257
biased	981	31	34	58	71	85	127
	982	30	32	58	69	89	104
	991	44	35	67	78	91	110
	1000	43	44	72	88	100	115
Unbiase	1001	31	34	62	85	63	119
	1004	43	8	74	102	74	133
	1013	29	31	61	89	63	119
	1026	45	46	70	103	82	135

Table 9: I_{CBO} - Collector-Base cut off current

Limits:	min	max	
		10000	pA

Expanded uncertainty (k=2):	80 pA

Note: All values were within the limits.

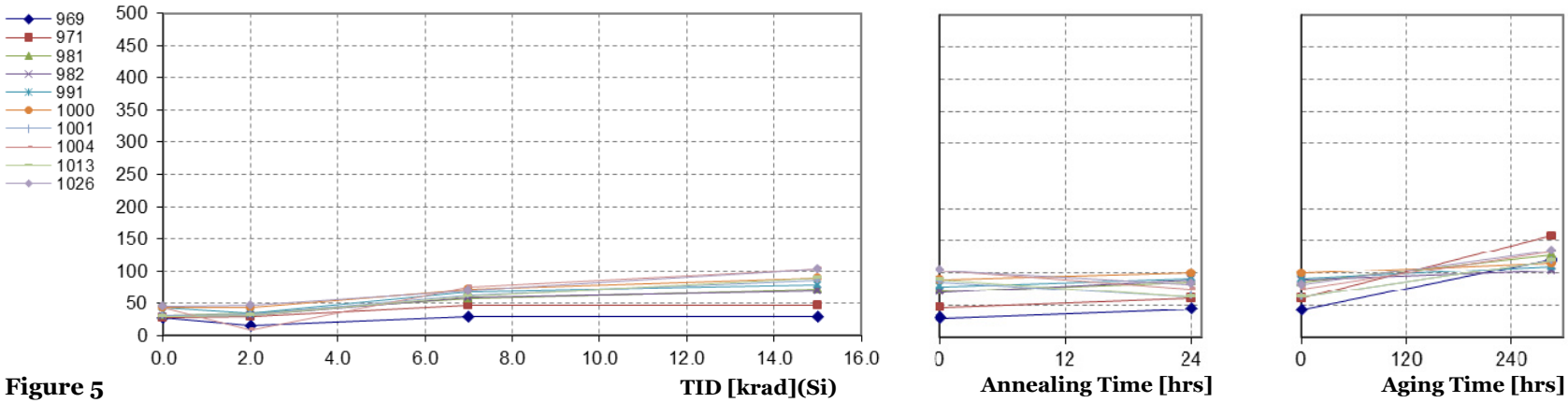

Figure 5

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
ref	969	1.5	1.3	1.2	1.4	1.3	0.9
	971	0.5	0.5	0.5	0.7	0.5	0.4
biased	981	0.5	0.5	0.6	1.3	1.3	0.5
	982	0.9	0.9	1.2	2.2	2.5	1.0
	991	0.7	0.7	0.8	1.6	1.5	0.6
	1000	0.4	0.5	0.7	2.0	3.1	0.6
Unbiase	1001	0.7	0.9	0.9	1.6	1.7	1.1
	1004	0.5	0.6	0.7	1.5	1.5	0.9
	1013	0.7	0.8	0.8	1.6	1.6	1.0
	1026	0.4	0.6	0.6	1.5	1.5	0.8

Table 10: I_{EBO} - Emitter-Base cut off current

Limits:	min	max	
		10000	pA

Expanded uncertainty (k=2):	1.5 pA

Note: All values were within the limits.

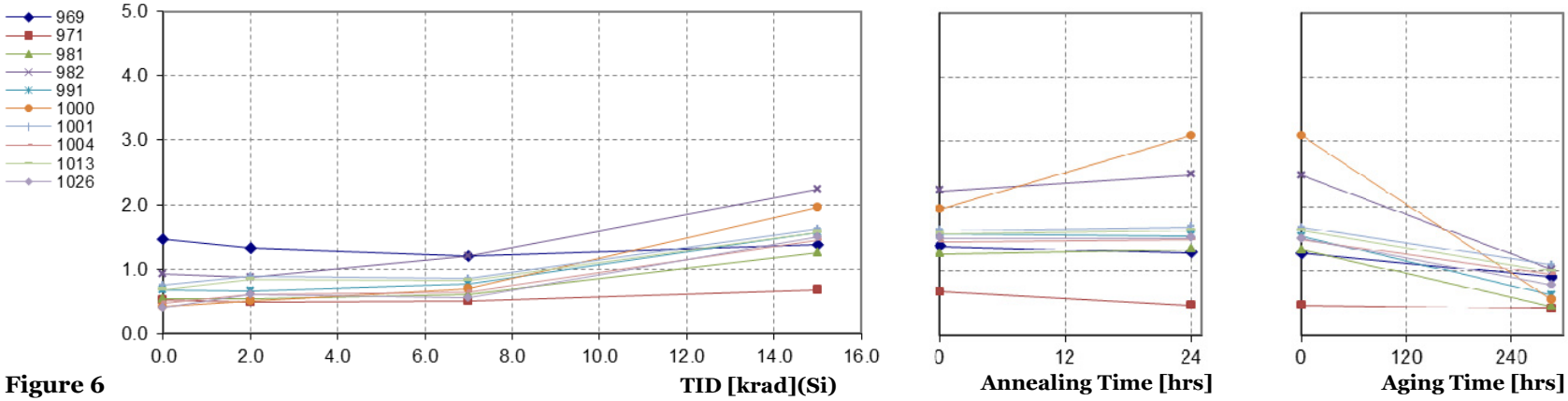

Figure 6

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
ref	969	36.2	35.5	36.0	34.8	35.0	34.4
	971	34.7	34.1	34.3	34.1	36.5	34.1
biased	981	35.4	34.8	36.6	38.7	39.2	39.1
	982	34.8	34.7	36.0	38.8	39.1	42.2
	991	36.3	36.3	37.8	41.2	42.0	41.4
	1000	34.6	34.1	35.4	37.6	38.2	39.0
Unbiase	1001	34.6	34.6	36.1	39.0	40.2	41.6
	1004	34.1	34.6	36.2	38.7	39.7	41.2
	1013	35.7	35.9	37.7	39.5	43.0	43.3
	1026	34.9	34.6	36.8	42.0	40.7	41.2

Table 11: $V_{CE(SAT)}$- Collector-Emitter saturation voltage

Limits:	min	max	
		350	mV

Expanded uncertainty (k=2):	1 mV

Note: All values were within the limits.

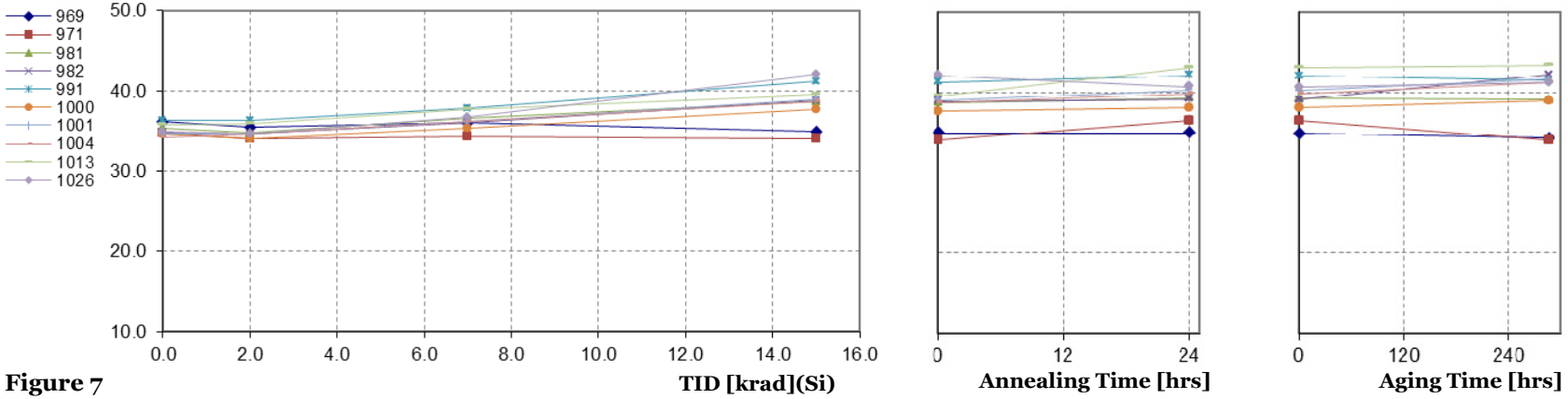

Figure 7

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
ref	969	552	527	538	525	527	524
	971	553	551	550	538	551	536
biased	981	542	516	450	392	387	418
	982	540	515	467	393	393	365
	991	540	494	441	370	365	419
	1000	591	549	476	406	393	434
Unbiase	1001	605	552	476	399	393	466
	1004	606	550	476	393	393	466
	1013	564	526	442	393	364	434
	1026	591	538	476	370	394	449

Table 12: h_{FE4} Forward Current Transfer Ratio

Limits:	min	max
	250	650

Expanded uncertainty (k=2):	15

Note: All values were within the limits. This parameter is the most sensitive to TID.

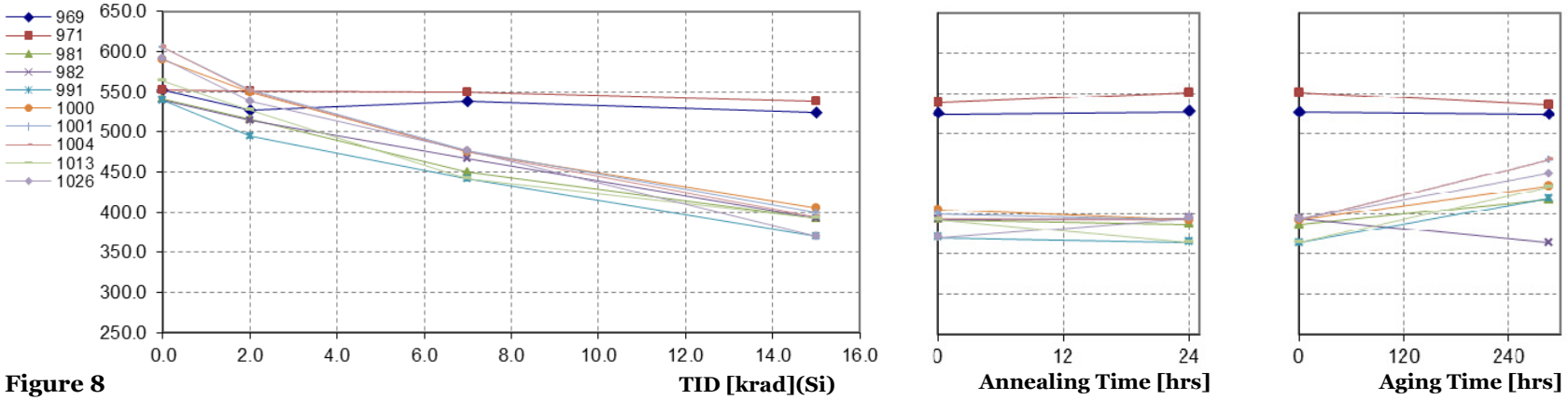

Figure 8

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
ref	969	535	511	508	505	508	506
	971	530	519	517	514	517	513
biased	981	506	485	464	424	422	438
	982	513	492	469	429	428	429
	991	511	489	460	418	419	440
	1000	550	525	491	446	444	464
Unbiase	1001	553	528	496	447	450	475
	1004	555	529	494	445	448	476
	1013	523	496	460	441	414	450
	1026	543	518	485	411	442	464

Table 13: h_{FE5} Forward Current Transfer Ratio

Limits:	min	max
		800

Expanded uncertainty (k=2):	15

Note: All values were within the limits.

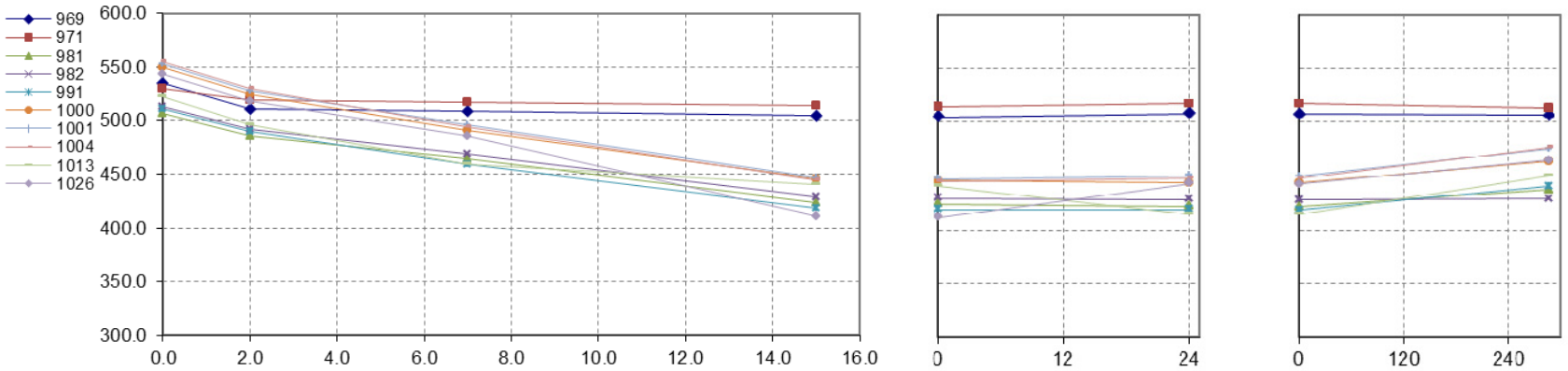

Figure 9

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 14.

Table 14 Summary of TID test results

nr.	Parameter	Remarks	Worst Case Bias Condition	Data in	
1	$V_{(BR)CBO}$	TID induced increase. All devices still within the limits.	none	Table 6	Figure 2
2	$V_{(BR)CEO}$	TID induced increase. All devices still within the limits.	none	Table 7	Figure 3
3	$V_{(BR)EBO}$	No evidence of TID induced degradation All devices within the limits.	none	Table 8	Figure 4
4	I_{CBO}	No significant evidence of TID induced degradation All devices within the limits.	none	Table 9	Figure 5
5	I_{EBO}	No significant evidence of TID induced degradation All devices within the limits.	none	Table 10	Figure 6
6	$V_{CE(SAT)}$	No significant evidence of TID induced degradation All devices within the limits.	none	Table 11	Figure 7
7	h_{FE4}	Evidence of TID dependent degradation. All devices still within the limits. Degradation amount and trend suggest this as the most sensitive parameter.	none	Table 12	Figure 8
8	h_{FE5}	Evidence of TID induced degradation. No evidence of Bias condition dependence. All devices still within the limits.	none	Table 13	Figure 9

Parameter h_{FE4} normalised data, see Table 15 , 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 10.
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 15 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 15: h_{FE4} Forward Current Transfer Ratio. [%]Variation with respect to the initial values observed during the TID test

		0 krad	2.0 krad	7.0 krad	15.0 krad	Anneal @R.T. 24 h	Ageing @100'C 286 h
ref	969	0%	-4.6%	-2.7%	-5.0%	-4.6%	-5.1%
	971	0%	-0.2%	-0.5%	-2.8%	-0.3%	-3.0%
Irradiated devices	981	0%	-4.8%	-16.8%	-27.5%	-28.6%	-22.8%
	982	0%	-4.6%	-13.5%	-27.3%	-27.1%	-32.5%
	991	0%	-8.4%	-18.2%	-31.5%	-32.4%	-22.4%
	1000	0%	-7.0%	-19.5%	-31.3%	-33.4%	-26.5%
	1001	0%	-8.8%	-21.4%	-34.1%	-35.1%	-22.9%
	1004	0%	-9.1%	-21.5%	-35.1%	-35.2%	-23.0%
	1013	0%	-6.6%	-21.6%	-30.3%	-35.4%	-23.1%
	1026	0%	-8.9%	-19.4%	-37.4%	-33.4%	-24.0%
	Min	-	-9.1%	-21.6%	-37.4%	-35.4%	-32.5%
	Max	-	-4.6%	-13.5%	-27.3%	-27.1%	-22.4%
	Average	-	-7.3%	-19.0%	-31.8%	-32.6%	-24.6%
	Std.Dev.	-	1.8%	2.8%	3.6%	7.4%	8.1%

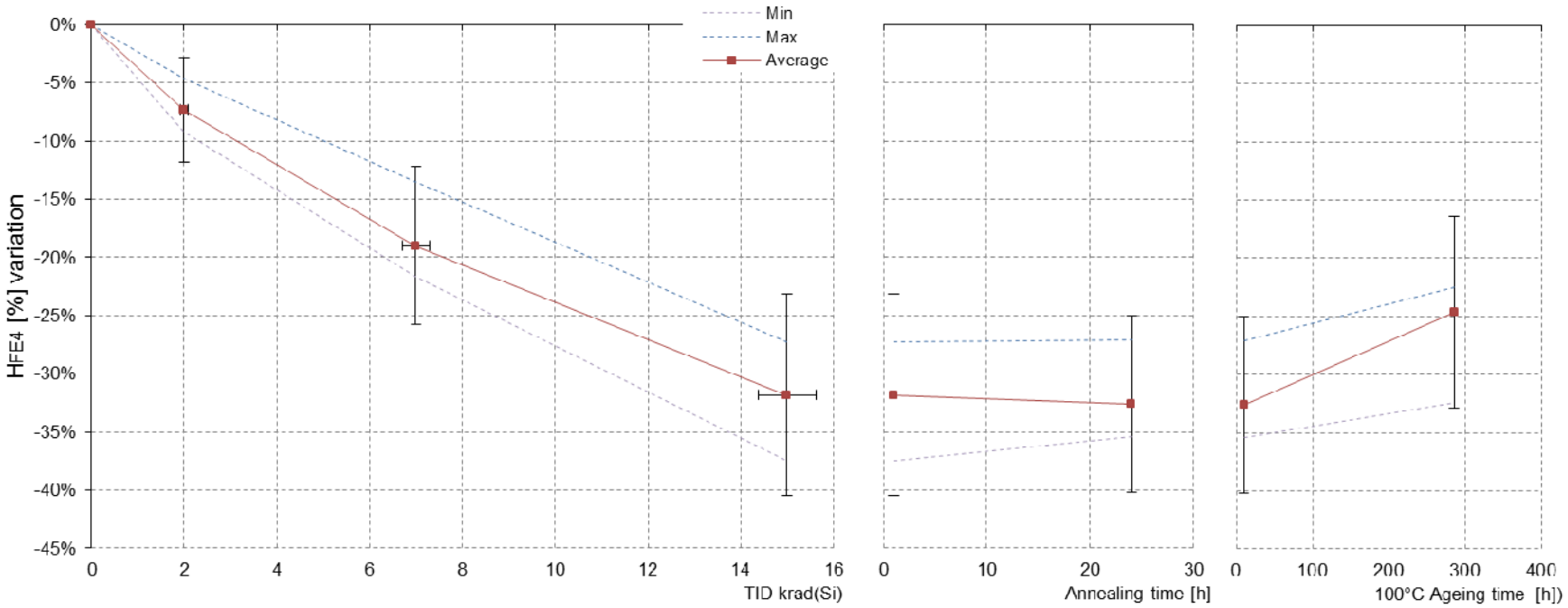
Min
Max
Average
0%
-5%
-10%
-15%
-20%
-25%
-30%
-35%
-40%
-45%
HFE4 [%] variation
0
2
4
6
8
10
12
14
16
TID krad(Si)
0
10
20
30
Annealing time [h]
0
100
200
300
400
100°C Ageing time [h])

Figure 10

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 dentification) 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 : 18.46 TBq *on date :* 03/04/2012

	units	Min.	Max.	Time-weighted Average
Temperature	°C	24.6	24.9	24.80
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.

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