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Arbeitsbericht 70/2011
October 2011

Co-60 Low Dose-Rate Irradiation of Electronic Components

Optocoupler
IS49

Manufacturer: Isocom, UK

Date Code: 1018
Wafer Lot:
LED: 14B08030-11J3821D0
PD: 14B09050-8460956050

T. Kündgen, S. Metzger, W. Lennartz

Abstract

This report presents results of TID irradiation tests with Co-60 on electronic optocouplers from Isocom, UK, performed at the Fraunhofer INT. The samples were provided by Tesat Spacecom GmbH.

Fraunhofer
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Table of Contents

List of Figures		**ii**
List of Tables		**ii**
References		**iii**
1	**Summary**	**1**
2	**Preface**	**3**
3	**Irradiated objects**	**4**
4	**Irradiation conditions**	**7**
5	**Measurement parameters**	**10**
6	**Results**	**14**
A	**Fraunhofer INT**	**36**
B	**Irradiation details**	**38**
C	**Certificate of TK100 irradiation source**	**41**
D	**Irradiation documentation**	**42**
E	**RVT-TES-11/025/STO, Issue B**	**43**

List of Figures

Figure 1: TOP-View 4
Figure 2: Bottom-View 4
Figure 3: ESD-box with the samples 5
Figure 4: Bias board 6
Figure 5: Samples placed bevor irradiation source 8
Figure 6: Bias Conditions 11
Figure 7: Forward Voltage 15
Figure 8: Diode Reverse Current 17
Figure 9: Diode Reverse Current Normalized 19
Figure 10: Collector Emitter Leakage Current 21
Figure 11: Collector Emitter Dark Current 23
Figure 12: Collector Current A 25
Figure 13: Collector Current B 27
Figure 14: Collector Current C 29
Figure 15: Collector Current D 31
Figure 16: Collector Current E 33
Figure 17: C-E Saturation Voltage 35
Figure 18: Picture of the TK100 irradiation facility 38

List of Tables

Table 1: Summary of irradiation conditions 1
Table 2: Environmental conditions 7
Table 3: Irradiation parameters 7
Table 4: Irradiation steps, Radiation Exposure 9
Table 5: Measurement parameters 10
Table 6: Environmental conditions during measurements 10
Table 7: Forward Voltage 14
Table 8: Diode Reverse Current 16
Table 9: Diode Reverse Current Normalized 18
Table 10: Collector Emitter Leakage Current 20
Table 11: Collector Emitter Dark Current 22
Table 12: Collector Current A 24
Table 13: Collector Current B 26
Table 14: Collector Current C 28
Table 15: Collector Current D 30
Table 16: Collector Current E 32
Table 17: C-E Saturation Voltage 34

References

[1] ESA/SCC Basic Specification No. 22900

[2] TEST METHODS FOR SEMICONDUCTOR DEVICES (MIL-STD-750)

[3] Tesat's irradiation test plan RVT-TES-11/025/STO, Issue B

[4] Performance Specification for Semiconductor Devices (MIL-PRF-19500)

[5] Test Specification RA.1801.021.10, IECQ-CECC Data sheet of IS49

[6] Website of Fraunhofer INT: http://www.int.fraunhofer.de

[7] Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, B.N. Taylor and C.E. Kuyatt, NIST Technical Note 1297, 1994, http://www.nist.gov/pml/pubs/tn1297/index.cfm.

1 Summary

The Fraunhofer Institute for Technical Trend Analysis (INT) carried out a series of Co-60 gamma irradiations on electronic Optocouplers from Isocom, UK, during August 2011 for Tesat Spacecom GmbH (Tesat).

1.1. Irradiated objects

Eleven samples of the Optocouplers provided by Tesat Spacecom GmbH were sent to Fraunhofer INT to irradiate ten of them with Co-60 gamma radiation with one being the reference. See chapter 3 for details in terms of Identification, Labelling, Marking and so on.

1.2. Irradiation conditions

Table 1: Summary of irradiation conditions

Parameter	Value and unit	Remarks
Irradiation facility	TK100	Co-60 gamma irradiation source
Temperature	24 ± 1°C	Room temperature
Dose steps	10, 25, 50, 75, 100 kRad(Si)	5 Irradiation Steps
Dose rate	0.30 kRad(Si)/h	See chapter B.3 for details on determination
Start of irradiation	2011-08-21 04:00	Whole period, details see chapter 4.4.
End of irradiation	2011-09-04 08:40	
Annealing	24h RT, 168h @ 100°C	

1.3. Measurement parameters

10 electrical measurements were done by Fraunhofer INT in accordance with the measurements standards and test methods of ESA, IEC, MIL.
See chapter 5 for details in terms of Performance, Test Sequence, Instrumentation and Condition.

The test plan based on the ESA Basic Specification No. 22900 in general and on Tesat's irradiation test plan [3] in particular.

1.4. Overview of results

The collector currents A and E underrun their given limits after the last irradiation up to 100 kRad(Si) and most of them also after the annealing.

All other parameters were within the given limits.

All devices were functional after a total dose of 100 kRad(Si) and the following annealing.

ON- and OFF-mode devices behave NOT different during the irradiation and annealing for all parameters.

During the measurement of the "Diode Reverse Current" the reference also showed relative large deviations. So a second set of data was generated where the results of the samples were compensated with the respective reference data. These results "Diode Reverse Current Normalized" can be found in chapter 6.2*.

2 Preface

This report describes the conduction and (if applicable) the analysis of irradiation experiments at Fraunhofer INT. This report complies with the relevant documents issued by ESA, IEC and other authorities. These require a variety of information that might distract the reader from the main content of the report. Therefore some of the requested information is moved to the appendixes.

Chapter 3 describes the samples as they were received from the customer. In chapter 4 the irradiation conditions are presented, followed by the description of the test equipment and the measurements in chapter 5. Chapter 6 shows the results of the measurements. In appendix A all information about Fraunhofer INT as an institution can be found. Appendix B depicts the technical details of the used irradiation facilities, their properties, and the applied dosimetry.

This report describes an irradiation test ordered by

- Tesat-Spacecom GmbH & Co.KG
  Gerberstraße 49
  D-71522 Backnang

The ordering customer is referred to as Tesat in the following of this report.

The technical details of this campaign were discussed between Stefan Metzger (INT) and Hartwig Storm (Tesat). All samples irradiated in this project were provided by Tesat. The purchase order is identified with U07-4500450933 dated 2011-07-14.

3 Irradiated objects

3.1. Sample identification

The part number was *IS49*.

The package type was SMD, type *LCC-6*.

The component designation was *IS49*.

The manufacturer was *Isocom, UK*.

The date code of the DUTs was *1018.*

The Wafer Lot was *LED: 14B08030-11J3821D0*
PD: 14B09050-8460956050

The DUTs were consecutively numbered from 23 to 33 with 23 being the reference device during the test.

3.2. Sample marking

The samples were mounted on an adapter (in this case a 8 DIL socket), to ease the exchanging, plugging and storage of the samples.

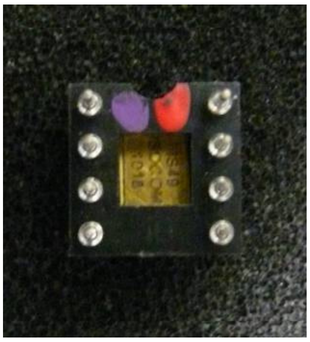
Figure 1:

TOP-View
(Sample marking)

X- ON/OFF-Mode

Figure 2:

Bottom-View
(PO-marking)



The samples or rather the socket were colour marked to differentiate the samples between each other and to separate the samples of the different purchase orders.

3.3. Sample savekeeping

The samples were stored in an Electro-Static Discharge (ESD) savekeeping box to handle them carefully during the measurements, the interim storage after the last measurement and the finally shipment.

Figure 3:

ESD-box with the samples

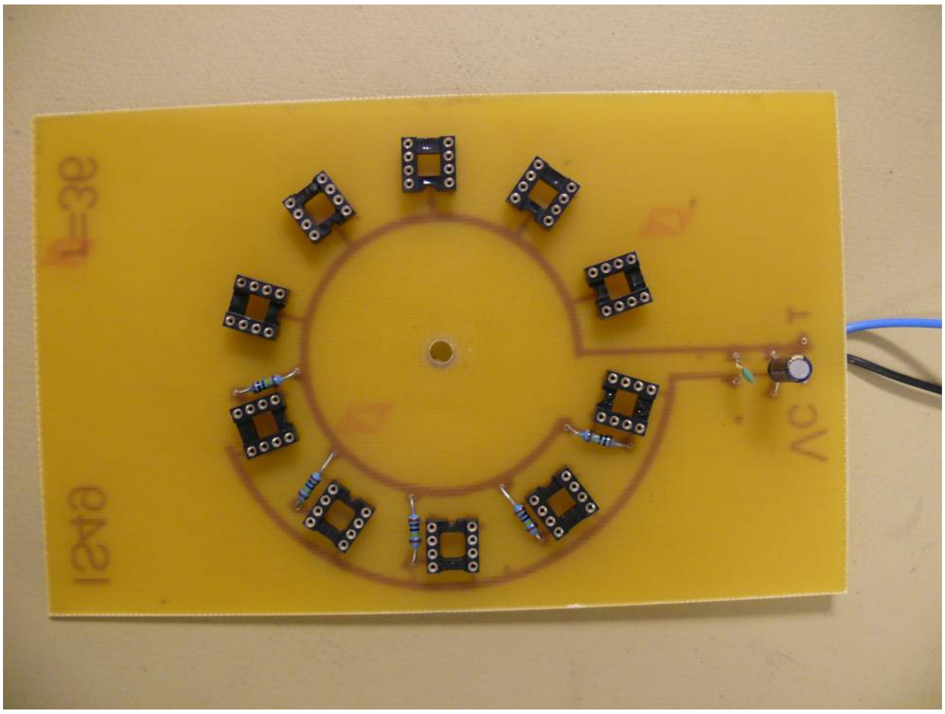
3.4. Sample holder

A custom-build board was manufactured to

- bias the samples according to the circuit-description of Tesat's irradiation test plan [3] (see also chapter 5.2),
- fix the samples under the irradiation source (see also 4.3 Geometry),
- irradiate the samples homogeneously.

Figure 4:

Bias board



3.5. Sample shipment

The samples were received July 2011 by Fraunhofer INT. The shipping box was inspected from outside and no visible damage was noticed. The transport case was opened after the temperature and humidity came into equilibrium with the room conditions.

After the end of irradiation the samples were visually inspected and stored in an ESD-box.

Up to the time of completion of this report, the samples were not sent back to Tesat.

4 Irradiation conditions

4.1. Environmental conditions

The environmental conditions for the irradiation test are given in Table 2.

Table 2: Environmental conditions

Parameter	Value and Unit	Remarks
Atmosphere	----	All irradiations steps are done in air
Humidity	20% to 60%	Non-condensing
Temperature	24 ± 1°C	During irradiation
Light	----	The samples are irradiated in ambient light

4.2. Irradiation parameters

The irradiation parameters realised in this campaign are shown in Table 3.

Table 3: Irradiation parameters

Parameter	Value and Unit	Remarks
Irradiation source	TK100	Co-60 gamma radiation with mean energy of 1.25 MeV
Nominal activity	136 GBq (3.68 Ci).	at 2011-08-21
Dose steps	10, 25, 50, 75, 100 kRad(Si)	5 Irradiation Steps
Dose rate	0.30 kRad(Si)/h	See chapter B.3 for details on determination
Dose uncertainty	5.7 %	Extended uncertainty with a coverage factor k=2
Non-Uniformity	6.8 %	Total deviation relative to mean dose value

4.3. Geometry

The irradiation parameters correspond to a sample-distance of 11.72 cm from the source.

Figure 5:

Samples placed bevor irradiation source

4.4. Irradiation steps

The irradiation was conducted in steps shown in Table 4.

Table 4:

Irradiation steps, Radiation Exposure

Messreihe Gamma-Bestrahlung

Firma	TESAT
Bauteil	IS49
Projektnummer	NEO-11-031

Anzahl der Messungen:	5
Messzeit:	01:00:00

Start der ersten Bestrahlung	21.8.11 4:00

	Beginn	Benötigte Zeit	Vorgang	Ende
So	21.8.11 4:00:00	33:20:00	Bis 10 kRad	22.8.11 13:20:00
Mo	22.8.11 13:20:00	01:00:00	Messung	22.8.11 14:20:00
Mo	22.8.11 14:20:00	50:00:00	Bis 25 kRad	24.8.11 16:20:00
Mi	24.8.11 16:20:00	01:00:00	Messung	24.8.11 17:20:00
Mi	24.8.11 17:20:00	86:40:00	Bis 51 kRad	28.8.11 8:00:00
So	28.8.11 8:00:00	01:00:00	Messung	28.8.11 9:00:00
So	28.8.11 9:00:00	80:00:00	Bis 75 kRad	31.8.11 17:00:00
Mi	31.8.11 17:00:00	01:00:00	Messung	31.8.11 18:00:00
Mi	31.8.11 18:00:00	86:40:00	Bis 101 kRad	4.9.11 8:40:00
So	4.9.11 8:40:00	01:00:00	Messung	4.9.11 9:40:00
So	4.9.11 9:40:00	24:00:00	24h RT	5.9.11 9:40:00
Mo	5.9.11 9:40:00	01:00:00	Messung	5.9.11 10:40:00
Mo	5.9.11 10:40:00	168:00:00	168h 100°C	12.9.11 10:40:00
Mo	12.9.11 10:40:00	01:00:00	Messung	12.9.11 11:40:00

Kontrolltabelle

Messungen	1	2	3	4	5
Dosis [kRad (Si)]	10,00	25,00	51,00	75,00	101,00
Dosisleistung [kRad (Si/hr)]	0,30	0,30	0,30	0,30	0,30

5 Measurement parameters

The measured parameters are listed in Table 5.

Table 5: Measurement parameters

Ref No.	Parameter	Symbol
1	Forward Voltage	V_F
2	Diode Reverse Current	I_R
3	Collector Emitter Leakage Current	$I_{C(leak)}$
4	Collector Emitter Dark Current	I_{CE0}
5	Collector Current A	I_{Ca}
6	Collector Current B	I_{Cb}
7	Collector Current C	I_{Cc}
8	Collector Current D	I_{Cd}
9	Collector Current E	I_{Ce}
10	C-E Saturation Voltage	$V_{CE(SAT)}$

5.1. Environmental conditions

The environmental conditions during measurements are given in the following table.

Table 6: Environmental conditions during measurements

Parameter	Value and Unit	Remarks
Atmosphere	----	All measurement and annealing steps are done in air
Humidity	20% to 60%	Non-condensing
Temperature	24 ± 1°C	During measurements
Temperature	24 ± 1°C	During first annealing (24h)
Temperature	100 ± 1°C	During second annealing (168h)
Light	----	The samples are measured in a lightproof measuring-case

5.2. Bias Conditions

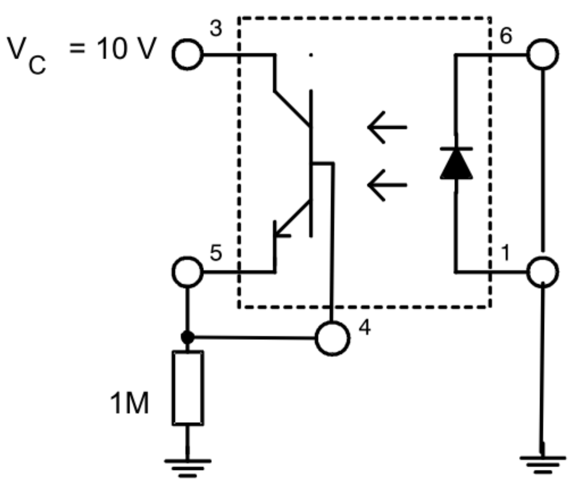
During the irradiation and the subsequent annealing 5 DUTs were biased (ON-Mode) according to the circuit-description of Tesat´s irradiation test plan [7] (see figure 6).

During transport from the irradiation site to the electrical measurement site and back again all terminals were shorted.

Figure 6:

Bias Conditions

ON-Mode **5 DUTs**



OFF-Mode **5 DUTs**

All pins shall be short circuited.

5.3. Measurement equipment

All measurements were performed with a 4155B Semiconductor Parameter Analyzer from Agilent, calibrated in 2011.

5.4. Measurement procedures

Parameters listed in Table 5 were tested before and after each radiation step and each annealing step (see also 5.5 Test Sequence).

The conditions are defined in Tesat´s irradiation test plan [7] and in the test specification [5].

The measurements were done by Fraunhofer INT in accordance with the measure-ments standards and test methods of ESA, IEC, MIL.

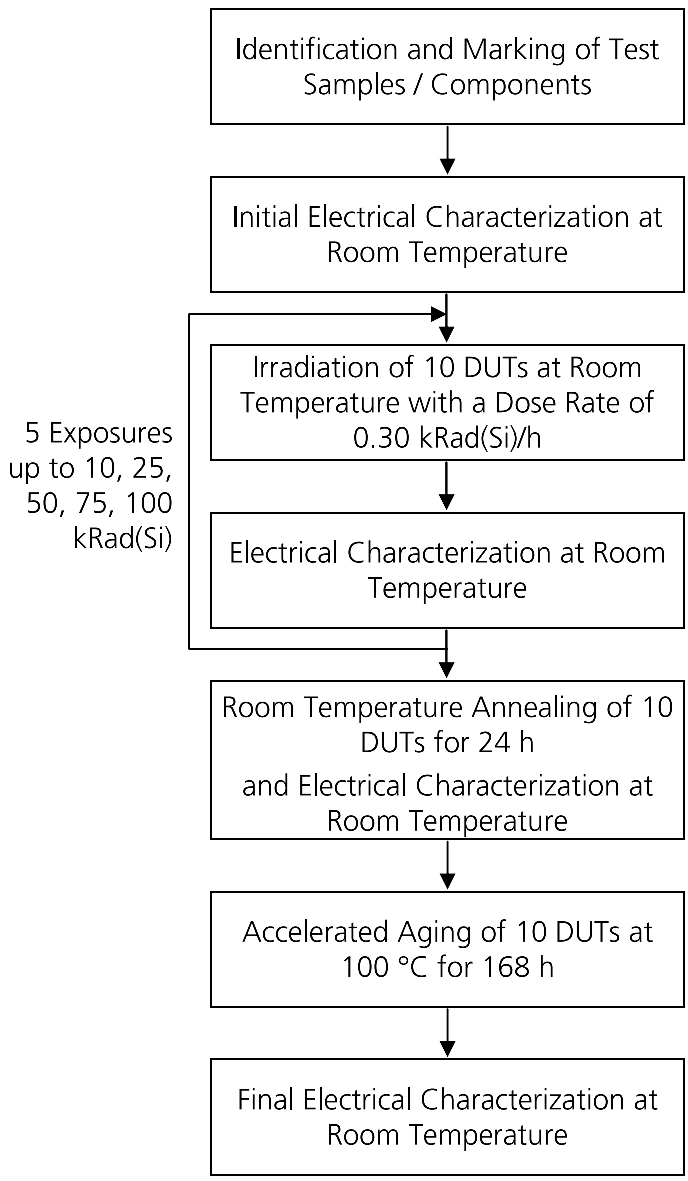
The measuring of all parameters did not exceed two hours.

The time interval between the completion of an exposure and the following electrical measurements was less than 15 minutes.

Measurement parameters

5.5. Test Sequence

The test sequence is shown in form of a flow chart.



6 Results

6.1. Forward Voltage V_F

Diode Forward Voltage V_F [V] — **IS49**

Conditions: I_F = 10 mA — Date Code: 1018

Limit: 1.40 … 1.46 V — Lot:

Accuracy: -- — LED: 14B08030- 11J3821D0

PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	**0**	**10**	**25**	**50**	**75**	**100**	**24 RT**	**168 h 100°C**
SN#24	1,4153	1,4095	1,4119	1,4128	1,4123	1,4114	1,4137	1,4109
SN#25	1,4154	1,4135	1,4132	1,4128	1,4142	1,4138	1,4157	1,4130
SN#26	1,4135	1,4108	1,4114	1,4114	1,4117	1,4120	1,4118	1,4119
SN#27	1,4113	1,4105	1,4092	1,4095	1,4100	1,4097	1,4098	1,4091
SN#28	1,4147	1,4118	1,4127	1,4129	1,4129	1,4127	1,4128	1,4123
Radiation-Mean On	**1,4140**	**1,4112**	**1,4117**	**1,4119**	**1,4122**	**1,4119**	**1,4127**	**1,4115**
Standarddeviation	**0,0017**	**0,0015**	**0,0016**	**0,0015**	**0,0015**	**0,0015**	**0,0022**	**0,0015**
Control: SN#23	1,4154	1,4143	1,4141	1,4154	1,4143	1,4140	1,4135	1,4131

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	**0**	**10**	**25**	**50**	**75**	**100**	**24 RT**	**168 h 100°C**
SN#29	1,4148	1,4131	1,4136	1,4140	1,4142	1,4143	1,4139	1,4133
SN#30	1,4118	1,4093	1,4105	1,4106	1,4108	1,4110	1,4109	1,4101
SN#31	1,4123	1,4091	1,4105	1,4109	1,4109	1,4111	1,4109	1,4108
SN#32	1,4126	1,4096	1,4110	1,4116	1,4113	1,4115	1,4113	1,4106
SN#33	1,4125	1,4096	1,4110	1,4107	1,4113	1,4104	1,4108	1,4107
Radiation-Mean Off	**1,4128**	**1,4102**	**1,4113**	**1,4116**	**1,4117**	**1,4116**	**1,4116**	**1,4111**
Standarddeviation	**0,0012**	**0,0017**	**0,0013**	**0,0014**	**0,0014**	**0,0016**	**0,0013**	**0,0013**
Control: SN#23	1,4154	1,4143	1,4141	1,4154	1,4143	1,4140	1,4135	1,4131

Table 7: Forward Voltage

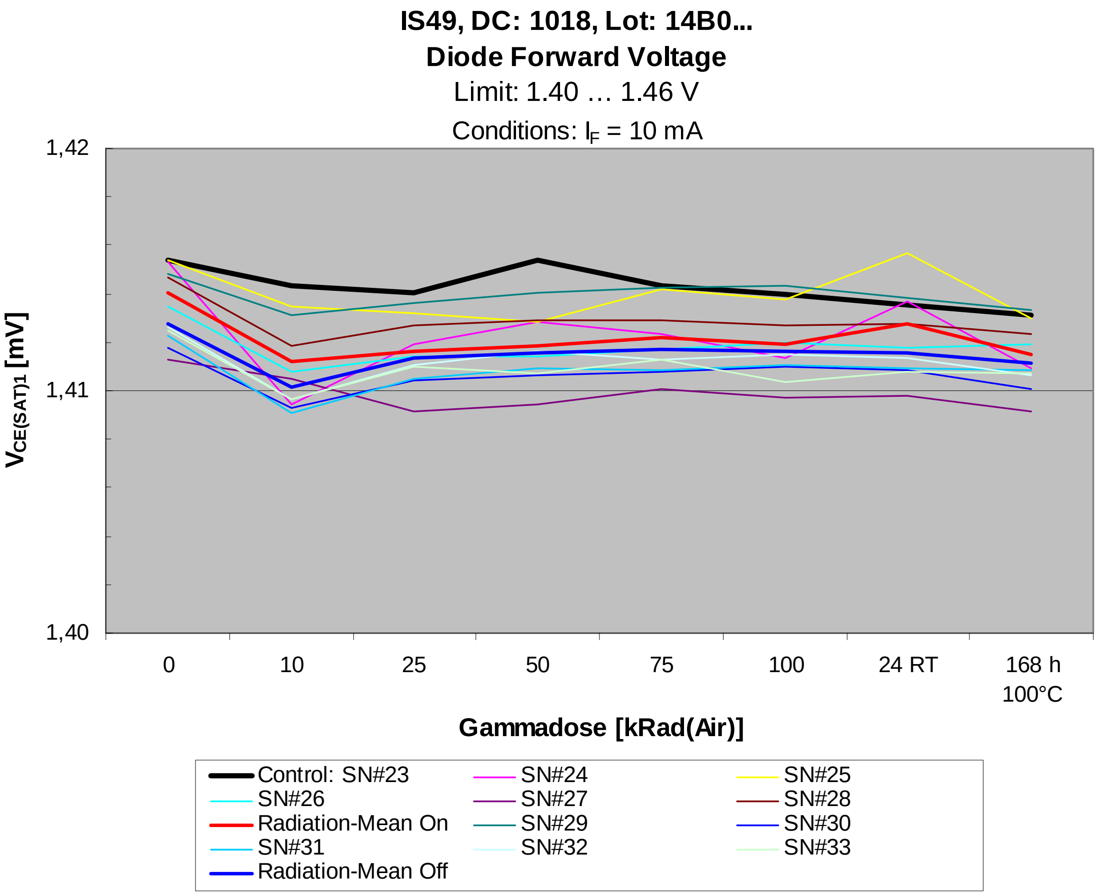


Figure 7: Forward Voltage

6.2. Diode Reverse Current I_R

Diode Reverse Current I_R [pA] **IS49**

Conditions: V_R = 2 V Date Code: 1018

Limit: < 100 µA Lot:

Accuracy: -- LED: 14B08030- 11J3821D0

PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	0,630	1,180	0,990	1,680	1,620	1,530	2,150	1,080
SN#25	0,650	0,660	0,670	0,680	0,940	0,900	1,060	0,600
SN#26	0,790	0,860	0,870	1,500	1,260	1,190	1,370	0,840
SN#27	0,660	0,830	0,770	0,900	1,300	1,520	1,390	0,700
SN#28	0,890	1,030	0,960	1,130	1,400	1,780	1,560	0,940
Radiation-Mean On	**0,724**	**0,912**	**0,852**	**1,178**	**1,304**	**1,384**	**1,506**	**0,832**
Standarddeviation	**0,112**	**0,199**	**0,133**	**0,413**	**0,247**	**0,342**	**0,403**	**0,190**
Control: SN#23	0,830	0,870	0,860	0,960	1,270	1,370	1,420	0,950

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	0,820	1,050	0,980	1,290	1,750	1,890	1,890	0,930
SN#30	0,720	0,790	0,780	0,970	1,190	1,530	1,310	0,810
SN#31	1,870	1,930	1,620	2,080	2,270	2,390	2,180	1,360
SN#32	0,750	0,980	0,830	1,220	1,380	1,800	1,530	1,000
SN#33	0,970	1,040	1,010	1,320	1,450	1,830	1,570	0,960
Radiation-Mean Off	**1,026**	**1,158**	**1,044**	**1,376**	**1,608**	**1,888**	**1,696**	**1,012**
Standarddeviation	**0,482**	**0,444**	**0,336**	**0,417**	**0,421**	**0,313**	**0,341**	**0,207**
Control: SN#23	0,830	0,870	0,860	0,960	1,270	1,370	1,420	0,950

Table 8: Diode Reverse Current

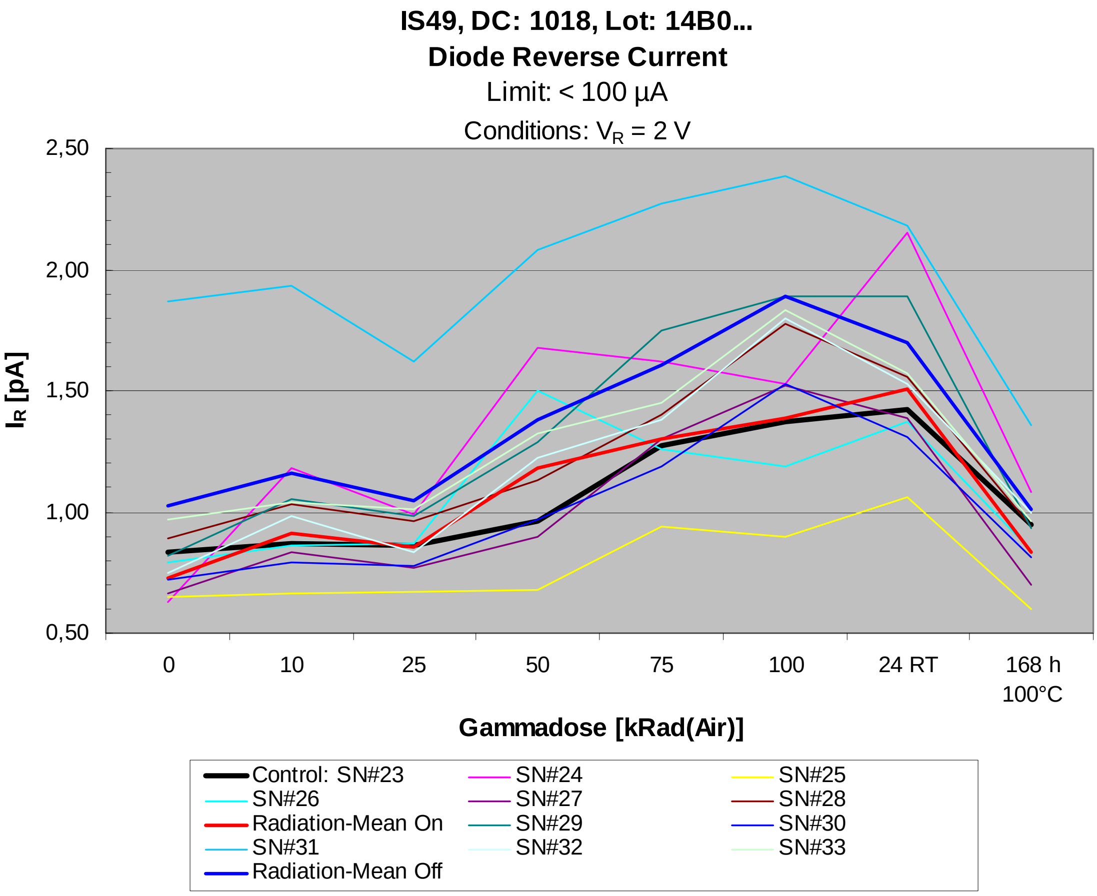


Figure 8: Diode Reverse Current

6.2* Diode Reverse Current I_R Normalized

Diode Reverse Current I_R [pA] _normed **IS49**

Conditions: V_R = 2 V Date Code: 1018

Limit: < 100 µA Lot:

Accuracy: -- LED: 14B08030- 11J3821D0

PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	0,866	1,376	1,196	1,786	1,416	1,226	1,796	1,196
SN#25	0,886	0,856	0,876	0,786	0,736	0,596	0,706	0,716
SN#26	1,026	1,056	1,076	1,606	1,056	0,886	1,016	0,956
SN#27	0,896	1,026	0,976	1,006	1,096	1,216	1,036	0,816
SN#28	1,126	1,226	1,166	1,236	1,196	1,476	1,206	1,056
Radiation-Mean On	**0,960**	**1,108**	**1,058**	**1,284**	**1,100**	**1,080**	**1,152**	**0,948**
Standarddeviation	**0,112**	**0,199**	**0,133**	**0,413**	**0,247**	**0,342**	**0,403**	**0,190**
Control: SN#23	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	0,820	1,050	0,980	1,290	1,750	1,890	1,890	0,930
SN#30	0,720	0,790	0,780	0,970	1,190	1,530	1,310	0,810
SN#31	1,870	1,930	1,620	2,080	2,270	2,390	2,180	1,360
SN#32	0,750	0,980	0,830	1,220	1,380	1,800	1,530	1,000
SN#33	0,970	1,040	1,010	1,320	1,450	1,830	1,570	0,960
Radiation-Mean Off	**1,026**	**1,158**	**1,044**	**1,376**	**1,608**	**1,888**	**1,696**	**1,012**
Standarddeviation	**0,482**	**0,444**	**0,336**	**0,417**	**0,421**	**0,313**	**0,341**	**0,207**
Control: SN#23	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066

Table 9: Diode Reverse Current Normalized

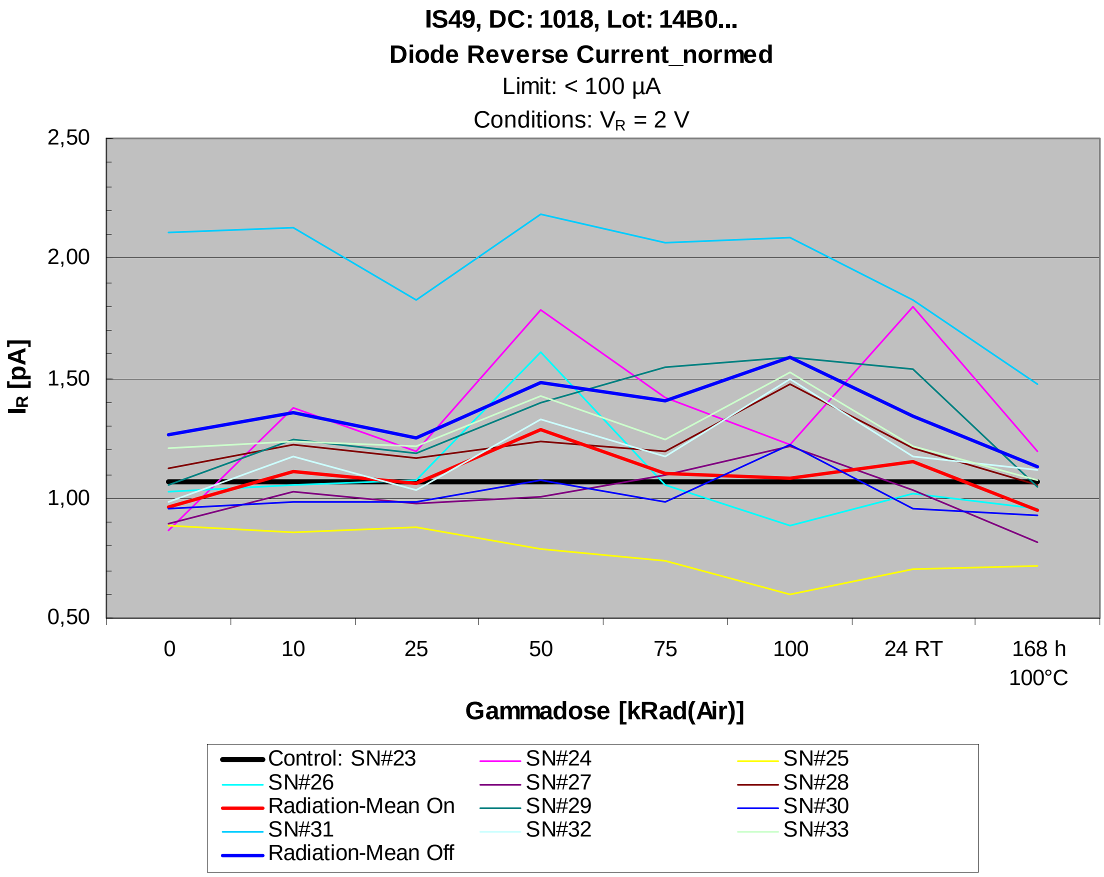


Figure 9: Diode Reverse Current Normalized

6.3. Collector Emitter Leakage Current $I_{C(leak)}$

Collector Emitter Leakage Curent $I_{C(leak)}$ [nA] **IS49**

Conditions: V_{CE} = 40 V Date Code: 1018

Limit: < 1.0 mA Lot:

Accuracy: -- LED: 14B08030- 11J3821D0

PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	1,688	10,334	2,150	0,893	0,995	1,092	1,050	2,996
SN#25	1,815	11,836	5,632	1,312	0,989	0,876	0,874	4,765
SN#26	1,956	11,054	2,153	0,909	0,994	1,090	1,036	3,131
SN#27	1,577	10,452	2,176	0,896	0,976	1,087	1,029	3,002
SN#28	1,898	11,373	2,328	1,100	1,038	1,142	1,091	3,179
Radiation-Mean On	**1,787**	**11,010**	**2,888**	**1,022**	**0,998**	**1,057**	**1,016**	**3,415**
Standarddeviation	**0,154**	**0,629**	**1,536**	**0,184**	**0,023**	**0,104**	**0,083**	**0,759**
Control: SN#23	1,794	2,031	2,050	2,184	2,260	2,092	2,154	1,732

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	1,938	13,280	3,832	1,224	1,269	1,373	1,365	4,569
SN#30	1,989	11,878	2,948	1,091	1,220	1,359	1,338	4,346
SN#31	1,852	11,535	3,629	1,094	1,187	1,312	1,289	4,153
SN#32	2,091	16,020	5,834	1,532	1,435	1,448	1,442	5,183
SN#33	1,966	10,441	2,451	1,044	1,212	1,397	1,353	3,638
Radiation-Mean Off	**1,967**	**12,631**	**3,739**	**1,197**	**1,265**	**1,378**	**1,357**	**4,378**
Standarddeviation	**0,086**	**2,149**	**1,294**	**0,199**	**0,100**	**0,050**	**0,055**	**0,567**
Control: SN#23	1,794	2,031	2,050	2,184	2,260	2,092	2,154	1,732

Table 10: Collector Emitter Leakage Current

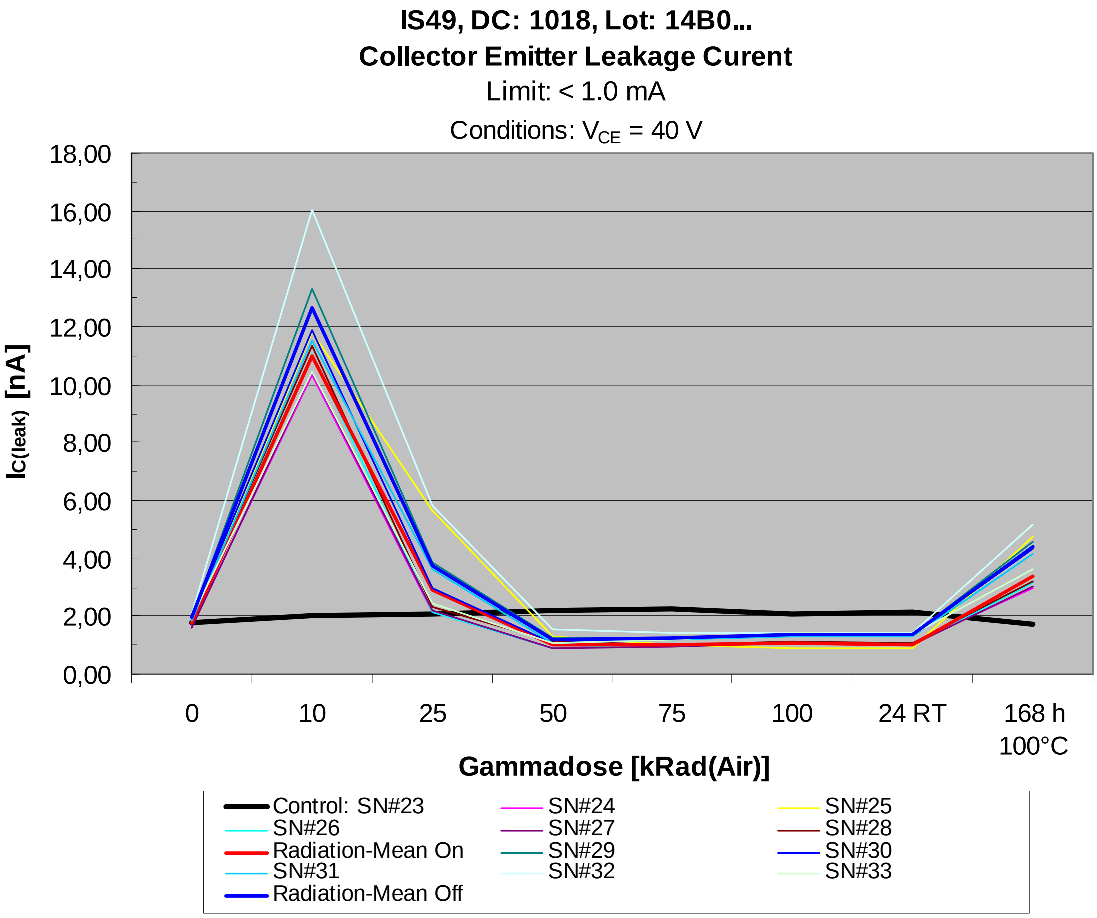


Figure 10: Collector Emitter Leakage Current

6.4. Collector Emitter Dark Current I_{CE0}

Collector-Emitter Cut-off Current I_{CE0} [nA] **IS49**

Conditions: V_{CE} = 20 V, I_F = 0 A Date Code: 1018

Limit: < 100 nA Lot:

Accuracy: -- LED: 14B08030- 11J3821D0

PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	0,732	4,801	1,105	0,495	0,584	0,667	0,634	1,521
SN#25	0,797	5,356	2,800	0,695	0,529	0,504	0,502	2,372
SN#26	0,875	5,116	1,111	0,506	0,572	0,659	0,627	1,595
SN#27	0,730	4,866	1,119	0,501	0,565	0,650	0,623	1,511
SN#28	0,823	5,355	1,185	0,542	0,591	0,679	0,654	1,593
Radiation-Mean On	**0,791**	**5,099**	**1,464**	**0,548**	**0,568**	**0,632**	**0,608**	**1,718**
Standarddeviation	**0,062**	**0,262**	**0,748**	**0,085**	**0,024**	**0,072**	**0,060**	**0,367**
Control: SN#23	0,789	0,904	0,983	0,895	0,946	0,835	0,868	0,841

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	0,851	6,009	1,906	0,670	0,744	0,843	0,835	2,266
SN#30	0,870	5,467	1,483	0,612	0,731	0,846	0,830	1,969
SN#31	0,813	5,199	1,763	0,611	0,698	0,806	0,798	2,055
SN#32	0,904	7,327	2,880	0,841	0,817	0,861	0,869	2,572
SN#33	0,853	4,992	1,219	0,619	0,739	0,862	0,845	1,818
Radiation-Mean Off	**0,858**	**5,799**	**1,850**	**0,670**	**0,746**	**0,843**	**0,835**	**2,136**
Standarddeviation	**0,033**	**0,935**	**0,633**	**0,098**	**0,044**	**0,023**	**0,026**	**0,293**
Control: SN#23	0,789	0,904	0,983	0,895	0,946	0,835	0,868	0,841

Table 11: Collector Emitter Dark Current

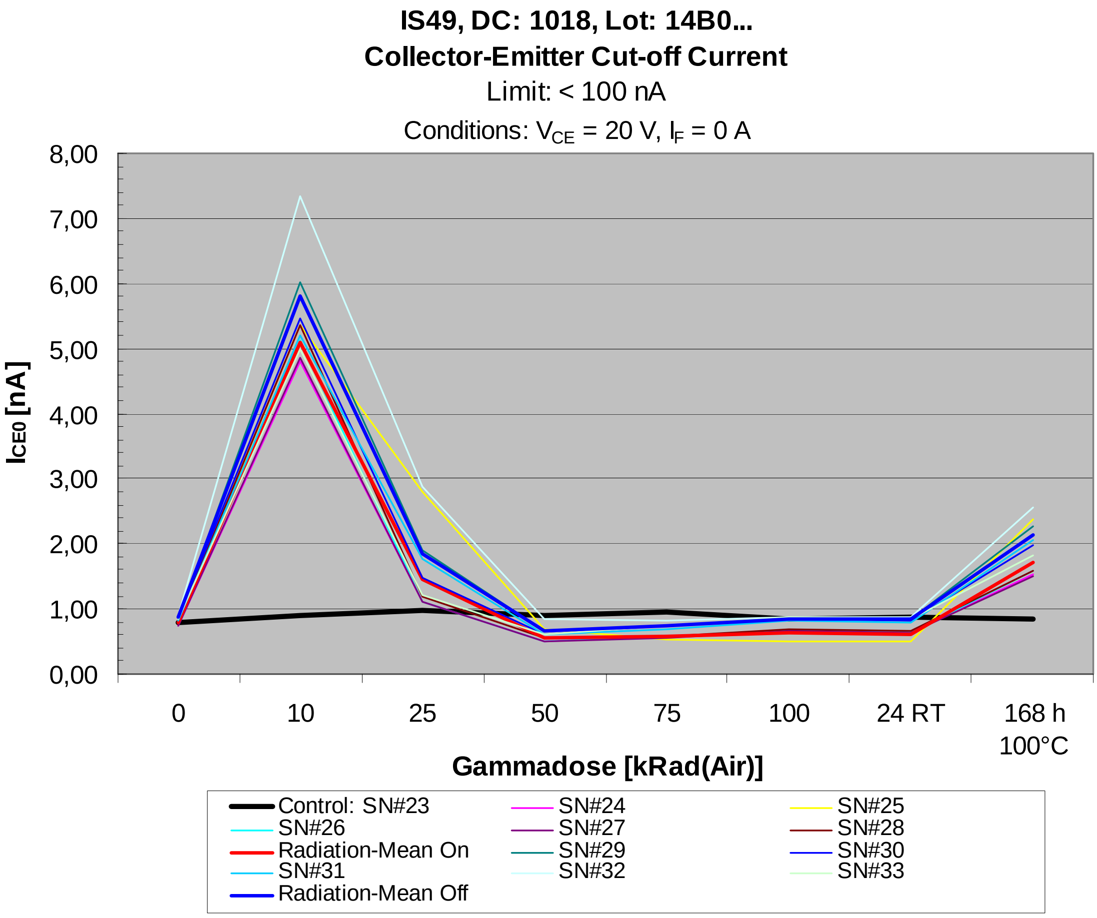


Figure 11: Collector Emitter Dark Current

6.5. Collector Current A I_{Ca}

Collector Current A I_{Ca} [mA] **IS49**
Conditions: V_{CE} = 1 V, I_F = 1 mA Date Code: 1018
Limit: > 4 mA Lot:
Accuracy: -- LED: 14B08030- 11J3821D0
PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	6,130	4,388	3,214	1,924	1,367	1,060	1,155	3,751
SN#25	6,403	5,179	4,145	3,016	2,335	1,794	1,891	3,925
SN#26	7,143	5,144	3,813	2,327	1,757	1,350	1,471	4,485
SN#27	5,413	3,879	2,831	1,676	1,223	0,926	1,012	3,329
SN#28	6,490	4,676	3,451	2,087	1,496	1,159	1,267	4,022
Radiation-Mean On	**6,316**	**4,653**	**3,491**	**2,206**	**1,636**	**1,258**	**1,359**	**3,902**
Standarddeviation	**0,627**	**0,545**	**0,511**	**0,511**	**0,438**	**0,337**	**0,341**	**0,420**
Control: SN#23	6,640	6,631	6,637	6,636	6,639	6,638	6,635	6,638

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	6,629	4,915	3,665	2,336	1,610	1,228	1,329	3,975
SN#30	6,510	4,655	3,423	2,003	1,325	1,026	1,123	3,851
SN#31	6,575	4,811	3,628	2,234	1,476	1,145	1,253	3,897
SN#32	8,193	6,346	4,943	3,409	2,439	1,917	2,049	5,109
SN#33	7,007	4,982	3,618	2,103	1,442	1,131	1,236	4,164
Radiation-Mean Off	**6,983**	**5,142**	**3,855**	**2,417**	**1,658**	**1,289**	**1,398**	**4,199**
Standarddeviation	**0,704**	**0,684**	**0,615**	**0,569**	**0,448**	**0,358**	**0,371**	**0,522**
Control: SN#23	6,640	6,631	6,637	6,636	6,639	6,638	6,635	6,638
Limit	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000

Table 12: Collector Current A

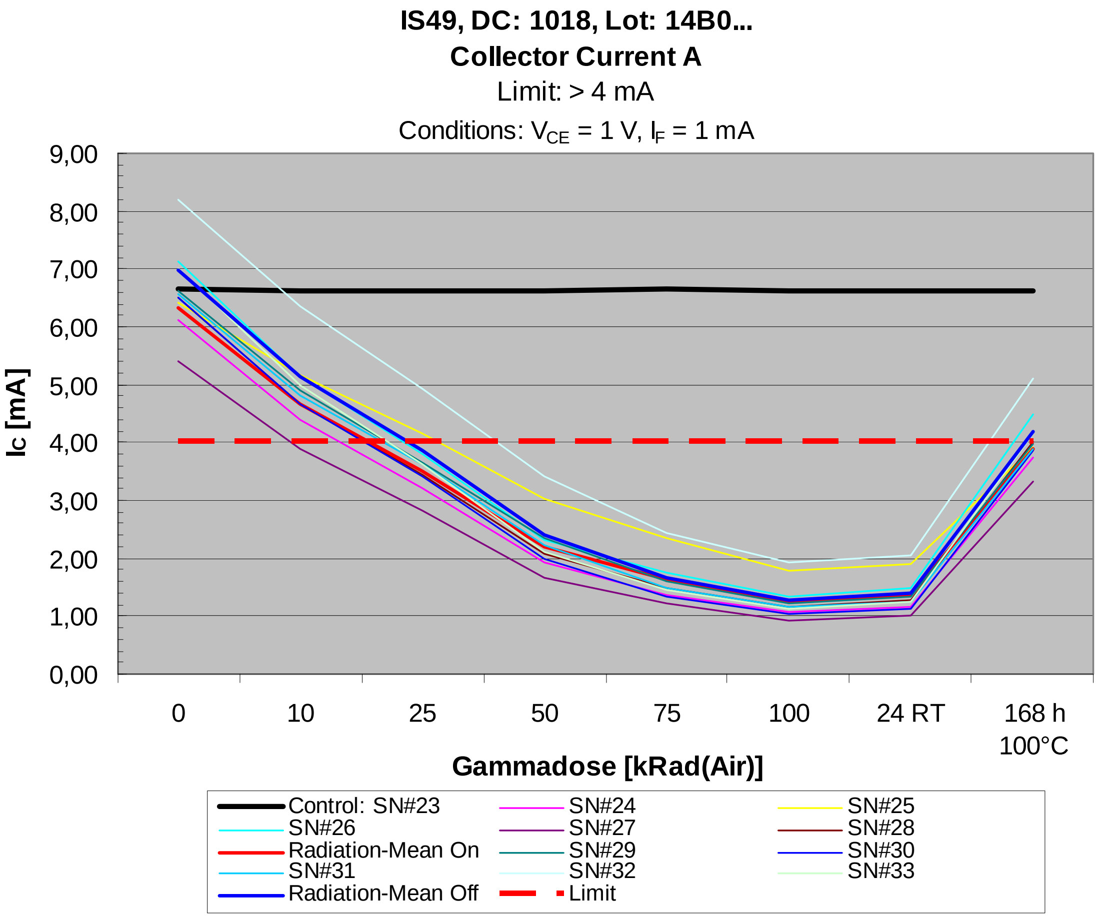


Figure 12: Collector Current A

6.6. Collector Current B I_{Cb}

Collector Current B I_{Cb} [mA] **IS49**

Conditions: V_{CE} = 1 V, I_F = 15 mA Date Code: 1018

Limit: > 15 mA Lot:

Accuracy: -- LED: 14B08030- 11J3821D0

PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	42,139	38,237	35,933	33,450	31,962	30,748	31,012	37,361
SN#25	43,735	41,018	38,918	36,807	35,590	34,196	34,513	38,010
SN#26	44,559	40,456	38,149	35,600	34,380	33,077	33,364	39,778
SN#27	41,200	37,422	35,189	32,691	31,427	30,132	30,416	36,649
SN#28	43,160	39,276	37,001	34,482	33,059	31,697	32,036	38,431
Radiation-Mean On	**42,959**	**39,282**	**37,038**	**34,606**	**33,284**	**31,970**	**32,268**	**38,046**
Standarddeviation	**1,320**	**1,495**	**1,534**	**1,647**	**1,715**	**1,668**	**1,681**	**1,180**
Control: SN#23	44,109	43,994	44,039	44,095	44,095	44,042	44,105	44,115

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	44,434	40,845	38,508	35,942	34,259	32,873	32,818	39,272
SN#30	42,034	38,350	36,220	33,602	31,851	30,650	30,919	37,224
SN#31	43,555	39,899	37,723	35,026	33,166	31,879	32,097	38,452
SN#32	49,285	45,672	43,329	40,652	38,854	37,494	37,590	43,878
SN#33	43,845	39,858	37,352	34,724	33,041	31,794	31,485	38,698
Radiation-Mean Off	**44,631**	**40,925**	**38,626**	**35,989**	**34,234**	**32,938**	**32,982**	**39,505**
Standarddeviation	**2,749**	**2,800**	**2,755**	**2,737**	**2,720**	**2,666**	**2,671**	**2,557**
Control: SN#23	44,109	43,994	44,039	44,095	44,095	44,042	44,105	44,115

Table 13: Collector Current B

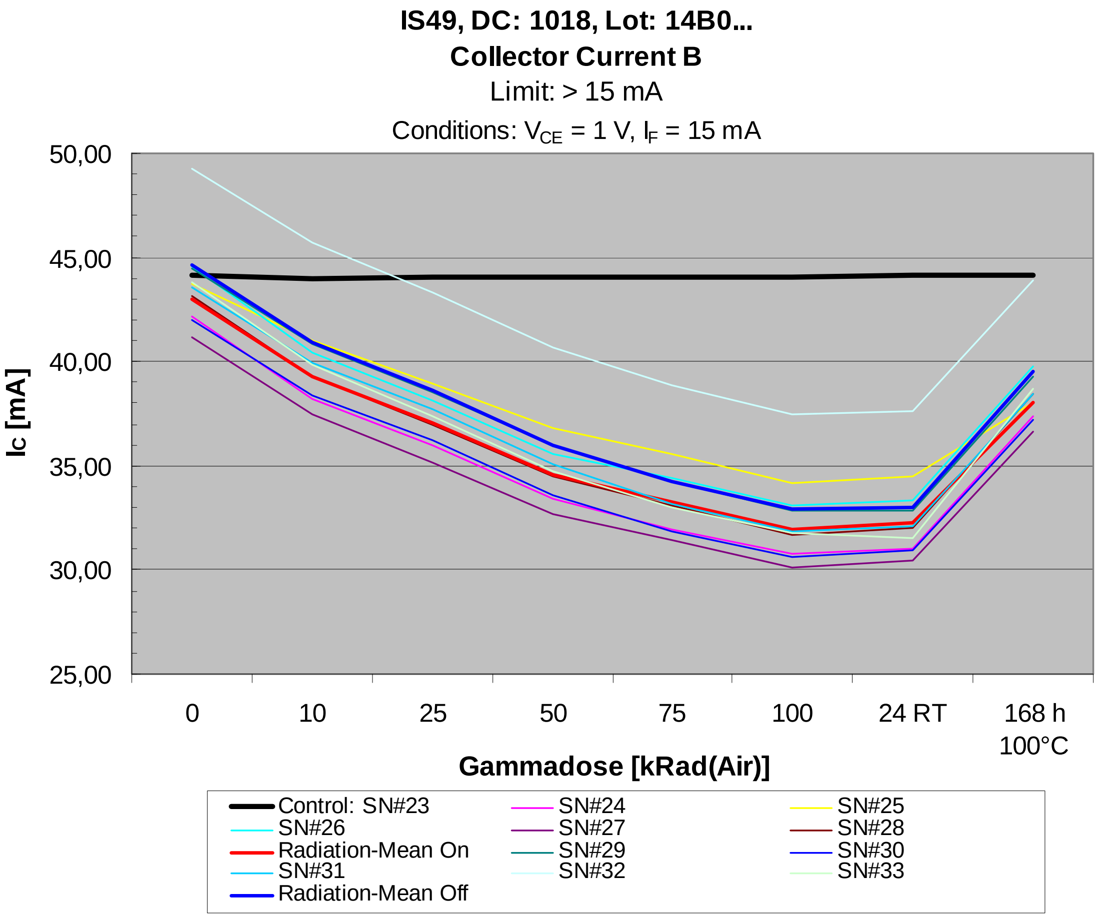


Figure 13: Collector Current B

6.7. Collector Current C I_{Cc}

Collector Current C I_{Cc} [mA] **IS49**
Conditions: V_{CE} = 5 V, I_F = 10 mA Date Code: 1018
Limit: > 35 mA Lot:
Accuracy: -- LED: 14B08030- 11J3821D0
PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	55,917	51,455	48,176	44,168	41,611	39,478	39,908	50,142
SN#25	58,425	55,398	52,644	49,536	47,572	45,536	45,810	51,900
SN#26	59,099	54,729	51,667	47,898	45,928	43,890	44,331	53,778
SN#27	54,330	49,826	46,521	42,385	40,020	37,666	38,103	48,651
SN#28	57,641	53,280	50,153	46,306	43,893	41,827	42,261	52,125
Radiation-Mean On	**57,082**	**52,938**	**49,832**	**46,058**	**43,805**	**41,679**	**42,083**	**51,319**
Standarddeviation	**1,944**	**2,305**	**2,504**	**2,855**	**3,076**	**3,191**	**3,144**	**1,971**
Control: SN#23	59,847	59,762	59,764	59,795	59,870	59,792	59,838	59,858

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	59,429	55,376	52,134	48,205	45,366	43,063	43,416	53,395
SN#30	57,258	53,096	50,043	45,934	42,960	40,852	41,239	51,530
SN#31	58,301	54,230	51,201	47,079	43,890	41,724	42,106	52,306
SN#32	65,051	61,407	58,531	54,927	52,251	50,309	50,612	59,213
SN#33	58,617	54,306	51,105	46,955	44,225	42,200	42,560	52,774
Radiation-Mean Off	**59,731**	**55,683**	**52,603**	**48,620**	**45,738**	**43,630**	**43,987**	**53,843**
Standarddeviation	**3,074**	**3,300**	**3,396**	**3,616**	**3,741**	**3,819**	**3,786**	**3,078**
Control: SN#23	59,847	59,762	59,764	59,795	59,870	59,792	59,838	59,858

Table 14: Collector Current C

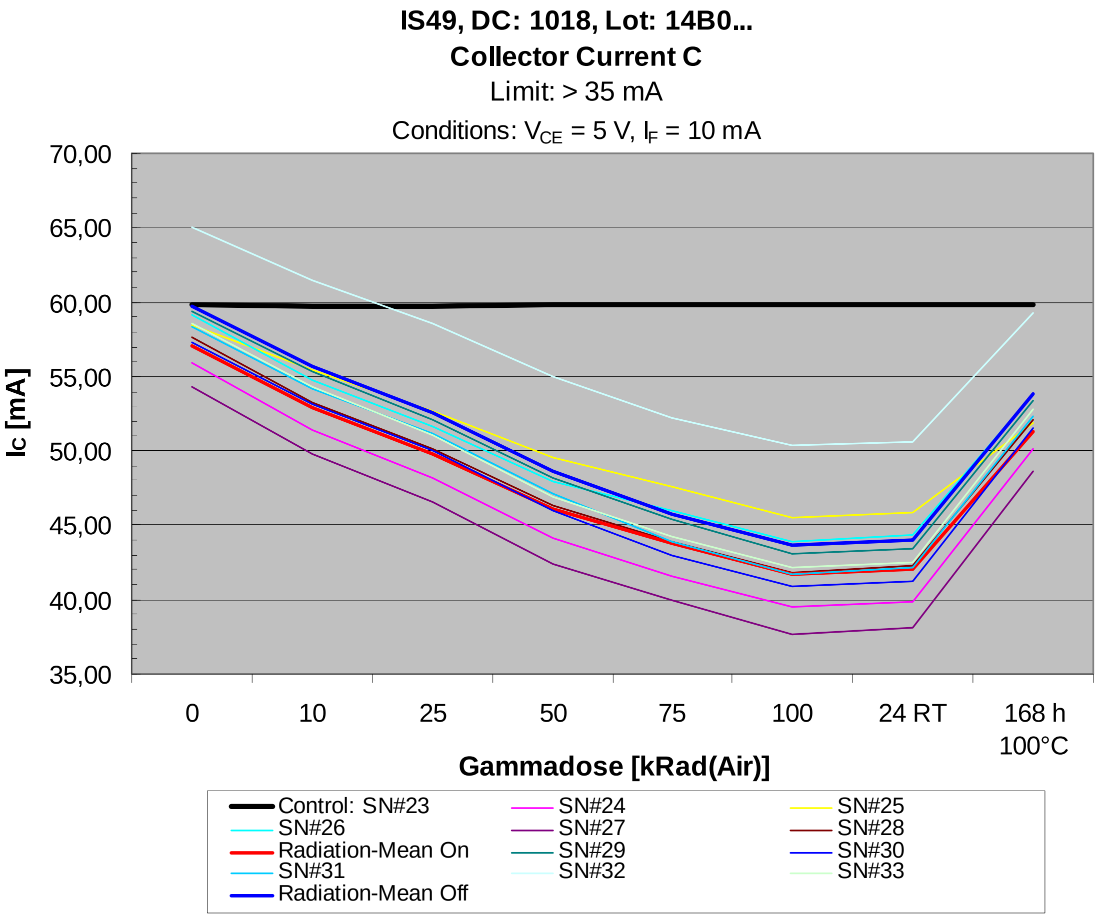


Figure 14: Collector Current C

6.8. Collector Current D I_{Cd}

Collector Current D I_{Cd} [mA] **IS49**

Conditions: V_{CE} = 5 V, I_F = 15 mA Date Code: 1018

Limit: > 15 mA Lot:

Accuracy: -- LED: 14B08030- 11J3821D0

PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	66,333	62,022	58,961	55,415	53,265	51,530	51,848	60,748
SN#25	69,127	66,211	63,608	60,751	59,090	57,251	57,523	62,891
SN#26	69,417	65,213	62,343	58,963	57,326	55,588	55,893	64,357
SN#27	64,896	60,591	57,540	53,983	52,061	50,142	50,464	59,538
SN#28	68,036	63,882	60,945	57,573	55,577	53,835	54,143	62,841
Radiation-Mean On	**67,562**	**63,584**	**60,679**	**57,337**	**55,464**	**53,669**	**53,974**	**62,075**
Standarddeviation	**1,919**	**2,294**	**2,461**	**2,706**	**2,874**	**2,896**	**2,879**	**1,914**
Control: SN#23	70,582	70,433	70,509	70,558	70,580	70,548	70,556	70,597

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	70,220	66,335	63,344	59,826	57,426	55,540	55,495	64,482
SN#30	67,323	63,421	60,616	57,046	54,550	52,829	53,083	61,974
SN#31	68,943	65,005	62,178	58,499	55,827	53,547	54,219	63,141
SN#32	76,117	72,577	69,913	66,637	64,323	62,570	62,814	70,569
SN#33	68,875	64,843	61,748	58,089	55,778	54,083	54,289	63,306
Radiation-Mean Off	**70,296**	**66,436**	**63,560**	**60,019**	**57,581**	**55,714**	**55,980**	**64,694**
Standarddeviation	**3,412**	**3,585**	**3,683**	**3,831**	**3,905**	**3,960**	**3,914**	**3,402**
Control: SN#23	70,582	70,433	70,509	70,558	70,580	70,548	70,556	70,597

Table 15: Collector Current D

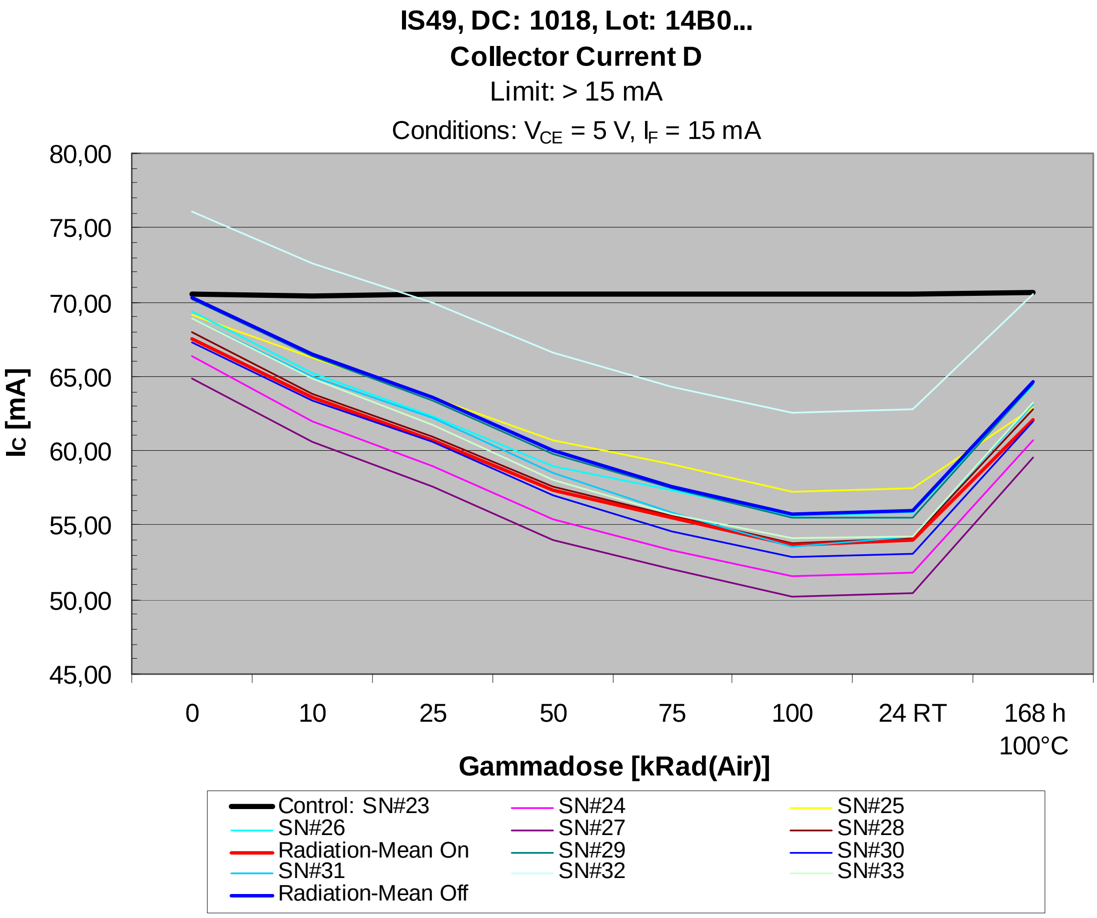


Figure 15: Collector Current D

6.9. Collector Current E I_{Ce}

Collector Current E I_{Ce} [mA] — **IS49**

Conditions: V_{CE} = 15 V, I_F = 1 mA — Date Code: 1018

Limit: > 5 mA — Lot:

Accuracy: -- — LED: 14B08030- 11J3821D0

PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	6,895	4,973	3,684	2,342	1,720	1,361	1,407	4,198
SN#25	7,234	5,878	4,699	3,488	2,763	2,182	2,228	4,418
SN#26	8,078	5,838	4,370	2,821	2,187	1,725	1,782	5,018
SN#27	6,038	4,359	3,220	2,028	1,521	1,181	1,220	3,700
SN#28	7,308	5,295	3,950	2,534	1,876	1,486	1,533	4,493
Radiation-Mean On	**7,111**	**5,269**	**3,985**	**2,642**	**2,013**	**1,587**	**1,634**	**4,366**
Standarddeviation	**0,739**	**0,635**	**0,578**	**0,554**	**0,485**	**0,387**	**0,390**	**0,479**
Control: SN#23	7,536	7,523	7,529	7,535	7,537	7,535	7,535	7,530

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	7,497	5,629	4,229	2,820	2,044	1,597	1,637	4,529
SN#30	7,348	5,317	3,952	2,475	1,731	1,365	1,405	4,378
SN#31	7,421	5,499	4,191	2,718	1,903	1,508	1,554	4,441
SN#32	9,322	7,289	5,709	4,053	3,027	2,436	2,491	5,829
SN#33	7,920	5,702	4,190	2,616	1,883	1,504	1,548	4,736
Radiation-Mean Off	**7,902**	**5,887**	**4,454**	**2,936**	**2,118**	**1,682**	**1,727**	**4,783**
Standarddeviation	**0,824**	**0,797**	**0,710**	**0,637**	**0,520**	**0,430**	**0,435**	**0,600**
Control: SN#23	7,536	7,523	7,529	7,535	7,537	7,535	7,535	7,530
Limit	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000

Table 16: Collector Current E

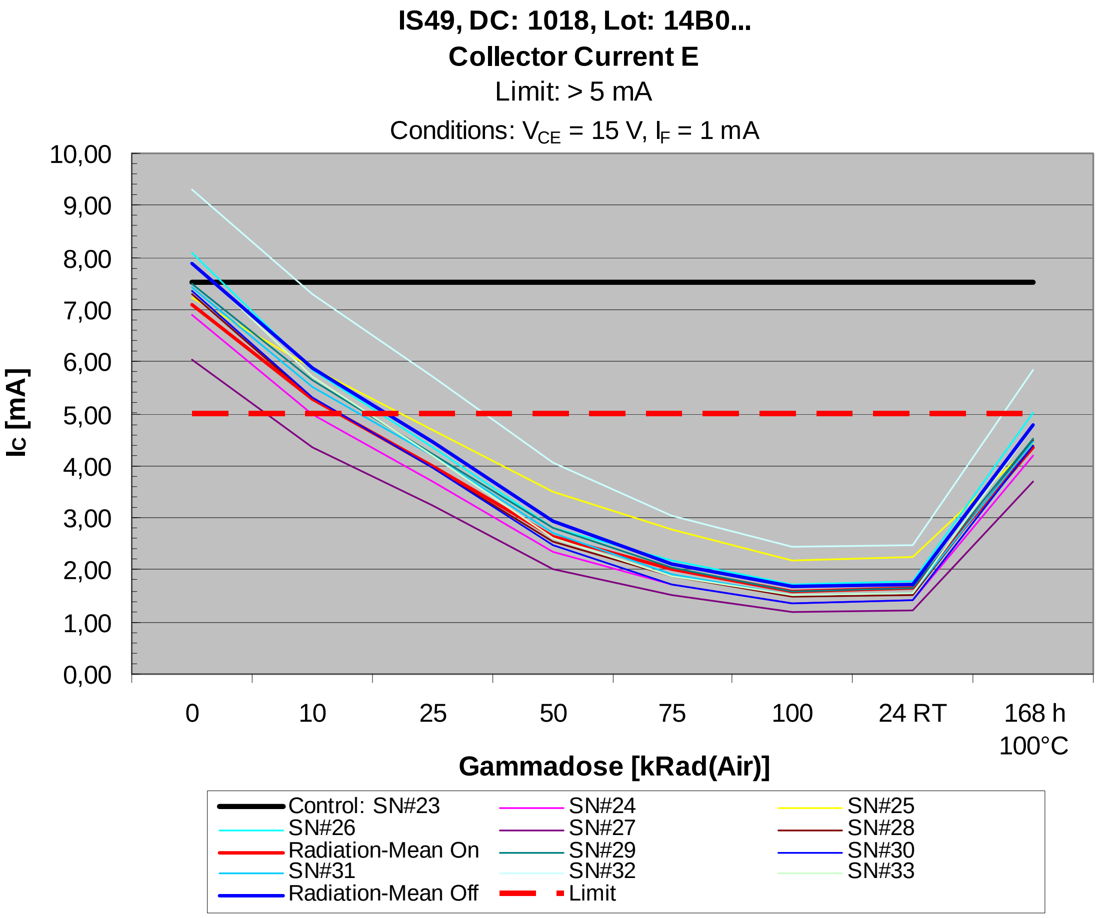


Figure 16: Collector Current E

6.10. C-E Saturation Voltage

C-E Saturation Voltage $V_{CE(SAT)}$ [mV] **IS49**

Conditions: I_C = 10 mA, I_F = 20 mA Date Code: 1018

Limit: < 0.22 V Lot:

Accuracy: -- LED: 14B08030- 11J3821D0

PD: 14B09050- 8460956050

ON-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#24	89,474	103,930	112,014	118,804	123,306	124,736	124,034	108,224
SN#25	91,432	97,176	103,950	110,012	115,058	118,994	116,374	104,624
SN#26	84,664	98,820	107,632	112,646	115,070	117,532	116,774	101,458
SN#27	91,326	106,398	115,034	120,860	123,952	126,708	125,698	109,032
SN#28	87,578	101,754	109,378	115,776	119,102	122,554	121,224	106,022
Radiation-Mean On	**88,895**	**101,616**	**109,602**	**115,620**	**119,298**	**122,105**	**120,821**	**105,872**
Standarddeviation	**2,842**	**3,734**	**4,219**	**4,413**	**4,290**	**3,837**	**4,196**	**3,024**
Control: SN#23	86,562	87,232	87,392	86,624	87,176	87,684	87,308	87,284

OFF-Mode	Co-60 Gammadose [kRad(Si)]						Annealing	
Counter	0	10	25	50	75	100	24 RT	168 h 100°C
SN#29	86,964	99,022	107,194	114,622	120,278	125,814	123,962	107,228
SN#30	90,342	103,952	113,484	120,294	125,858	128,222	127,976	109,752
SN#31	87,854	101,542	108,740	116,480	122,474	126,096	125,152	107,330
SN#32	77,356	89,818	96,828	103,352	108,042	111,144	111,720	95,734
SN#33	86,516	104,376	111,644	116,386	120,748	123,842	123,830	105,346
Radiation-Mean Off	**85,806**	**99,742**	**107,578**	**114,227**	**119,480**	**123,024**	**122,528**	**105,078**
Standarddeviation	**4,950**	**5,946**	**6,490**	**6,422**	**6,759**	**6,820**	**6,268**	**5,453**
Control: SN#23	86,562	87,232	87,392	86,624	87,176	87,684	87,308	87,284

Table 17: C-E Saturation Voltage

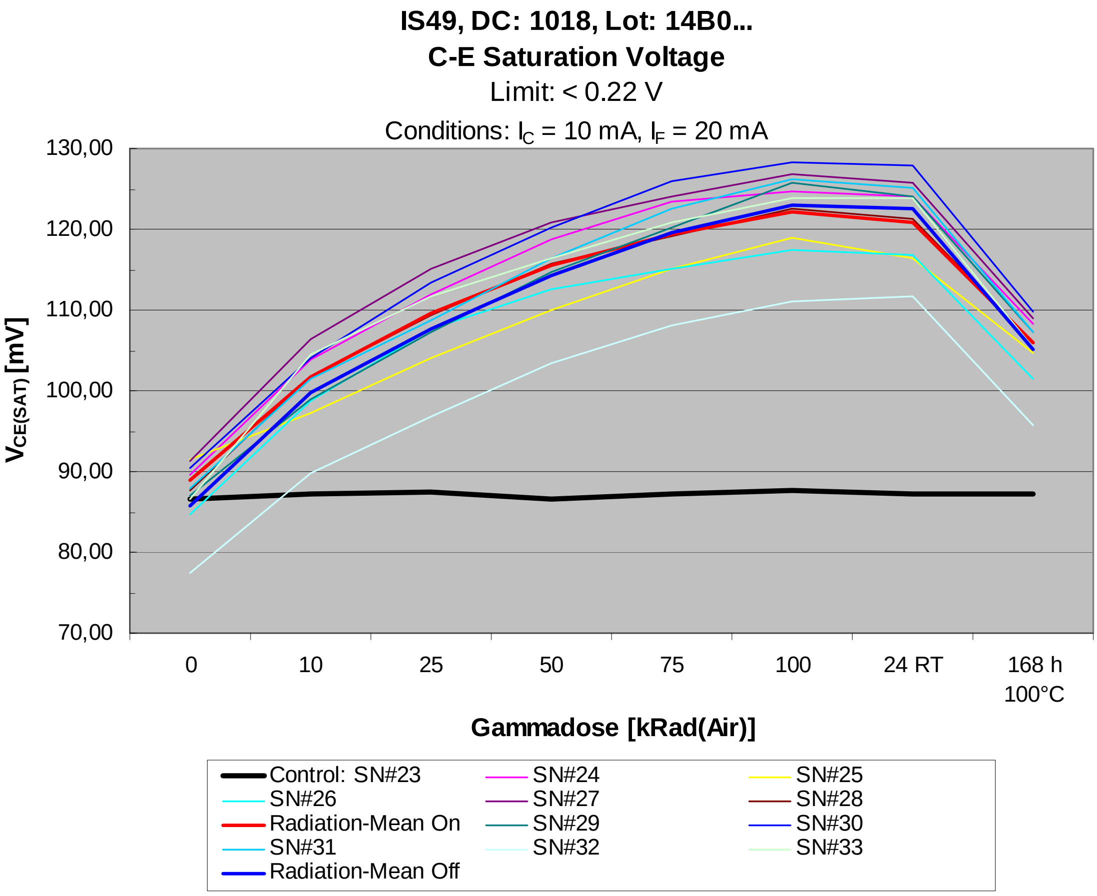


Figure 17: C-E Saturation Voltage

A Fraunhofer INT

A.1. About the institute

The Fraunhofer Institute for Technological Trend Analysis INT creates and continuously updates a comprehensive overview of the general research and technology landscape and of the entire spectrum of national and international technological developments. In addition to this general overview, we generate our own specialized analyses and forecasts in selected technological areas.

For more than 30 years, the Institute has been advising the German Federal Ministry of Defence on questions of technology and on how to plan and realize new research and technology projects. In recent years, research has increasingly been carried out also for other public institutions involved in security precautions and long-term changes in society. In addition to this, the INT performs its own experimental and theoretical research on the effects of ionizing radiation on electronic components and systems.

The Institute is equipped with state-of-the-art measurement technology. The major laboratory and large-scale devices are radiation sources and electromagnetic simulation facilities which cannot be found in this combination in any other civilian institution in Germany. Our main clients include authorities and organizations concerned with security matters and precautions, as well as aerospace. Further information can be found on the website [6].

A.2. Business unit Nuclear Effects in Electronics and Optics

For several decades the working group "Nuclear Effects in Electronics and Optics" (NEO) investigates the impact of ionising radiation on electronic, opto-electronic, and photonic components and systems.

The INT performs irradiation tests based on international standards and advises companies regarding radiation qualification and hardening for space applications. The knowledge obtained in years of radiation testing is also used for the development of new radiation sensor systems. The simulation facilities for our activities are installed at the INT itself and at external institutions and are accessible on regular basis.

A multitude of modern equipment to measure electrical and optical parameters is available. Furthermore our institute runs a precision mechanical workshop and an electronic laboratory. This enables us to conduct most of the irradiation tests without help or equipment of the customer.

The activities within NEO are described by:

- Radiation impact investigations on products intended to operate in all kinds of radiation environments
- Performing irradiation tests at the INT and external facilities
- Analysis and evaluation of measurements related to radiation
- Enabling the successful operation of components in typical radiation environments, such as space, nuclear facilities, medicine, or accelerators
- Advising users and manufacturers on the use of products in radiation environments by selecting, optimisation, and hardening
- Measurement of radiation induced attenuation in optical fibres and the effects in Fibre-Bragg-Gratings
- Development of new radiation sensors based on optical fibres and oscillating crystals
- Improvement of test procedures with IEC, IEEE, NATO, and IAEA

A.3. Irradiation facilities

Fraunhofer INT operates several irradiation facilities on site that are only dedicated to perform irradiation tests. For that purpose the design and operation characteristics are highly optimised from many decades of experience and to comply with all relevant standards and test procedures.

Furthermore Fraunhofer INT accesses regularly external facilities, partly with dedicated irradiation spots for exclusive use to Fraunhofer INT.

The used irradiation facilities are:

- Co-60 irradiation sources on site to simulate the effect of total dose
- External Co-60 irradiation sources for high dose and high dose rate irradiations
- Neutron generators on site to simulate the displacement damage of heavy particles
- Dedicated proton irradiation spot at the injector cyclotron of FZ Juelich to simulate the effects of solar and trapped protons
- Irradiation installation at the GSI Darmstadt to simulate the effect of single relativistic heavy ion impacts
- Flash X-ray facility on site for pulsed irradiation with photons and electrons
- 450 keV X-ray irradiation facility on site
- laser induced single event test system on site

The facilities used in the context of this work will be described in detail in the following sections.

B Irradiation details

B.1. Irradiation facility TK100

The irradiation was done at the TK100 facility of Fraunhofer INT.

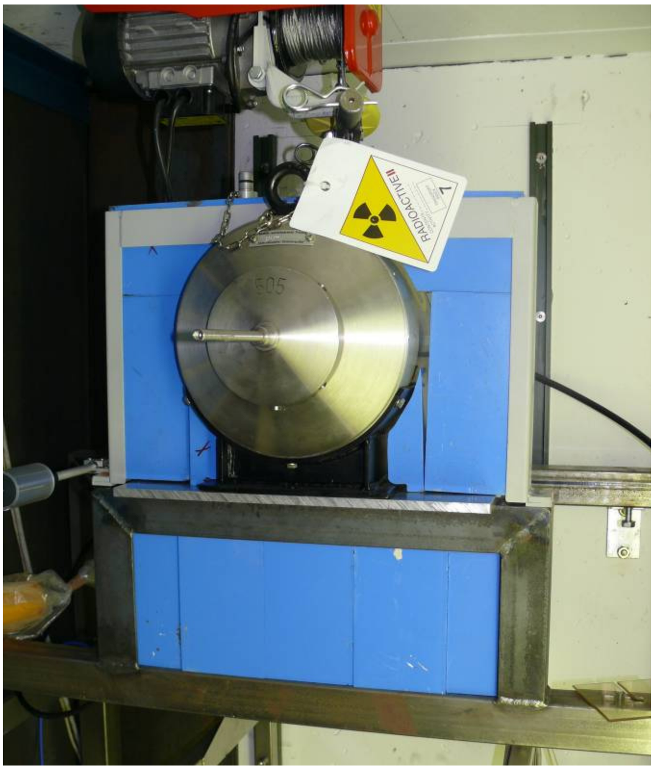
The TK100 is a Co-60 gamma irradiator manufactured by Sauerwein Isotopentechnik, Germany. Inside the shielding container is a small radioactive pellet with a diameter of 2 mm and a length of 3 mm. The activity decreases with a physical half-life of 5.27 years. The currently used radioactive pellet was installed in the irradiator in 2001.

The radioactive pellet is a X2163 type with the identification number HD 3286. The nominal activity at 2001-01-09 was 555 GBq corresponding to 15 Ci.

The certificate of the radioactive source can be found in appendix C

Figure 18:

Picture of the TK100 irradiation facility



In deactivated state the radioactive pellet is stored inside the shielding container allowing the operator to install the samples and conduct measurements without getting exposed to ionising radiation.

On activation, the radioactive source is pushed into the source guiding tube in less than a second irradiating the surrounding volume.

Currently the activity of the Co-60 source is about 136 GBq (corresponding to 3.68 Ci).

B.2. Radiation properties of TK100

The samples are irradiated with Co-60 gamma radiation. The radioactive Co-60 isotope decays by emitting beta radiation (i.e. electrons) into a highly excited Ni-60 isotope which emits two gamma photons to reach the stable ground state. The gamma radiation has two energy levels of 1.172 MeV and 1.332 MeV.

The gamma radiation of around 1 MeV is a penetrating radiation, so the samples are irradiated completely. The shielding of the source guiding tube, sample holder and other surrounding material between the actual source and the sample is negligible.

The radiation is emitted from a point-like source leading to a decreasing dose rate with increasing distance. The dose rates at two distances are proportional to the inverse square root of the corresponding distances. For example, doubling the distance decreases the dose rate by a factor of four.

B.3. Dosimetry at TK100

The dosimetry is done regularly with calibrated dosimeters and ionisation chambers manufactured by Wellhöfer, Germany, and PTW Freiburg, Germany.

The dose rates obtained at varying distances between 2 cm and 50 cm and in different directions relative to the source are used to develop a model of the dose rate distribution around the source as a function of distance and direction. The dose rate of an individual measurement is scaled to a reference date taking the half-life of the radioactive isotope into account. This model is constantly checked and improved with each additional measurement of dose rates.

As a result a reliable description of the dose rates inside a specific volume arranged in a given geometry in the vicinity of the irradiation source is available.

The uncertainties of the reported dose rates are given by an uncertainty evaluation according to [7] and mainly result from the uncertainties of the dosimetry and positioning of the samples.

The uncertainty evaluation for this irradiation can be found in appendix D.

C Certificate of TK100 irradiation source

MDS Nordion Haan GmbH

Tel.: 02129 55121 Telefax 55155

Frauenhofer Institut
Euskirchen Kd.Nr.20149

Prüfzeugnis Nr.	01- 23	Sealed Radioactive Source Test Report
Radioaktiver Stoff	CO-60	Radioactive Material
Aktivität (GBq/Ci)	555.0 / 15.0	Activity (GBq/Ci)
Datum	9.JAN.01	Date
Abmessung	2X3 mmxmm	Dimension
Kapsel Typ	X2163	Capsule Type
Strahler Nr.	HD3286	Serial No.
ISW - Nr.	01019	ISW - No.
Zertifikat - Nr.	GB/371/S-85	Certificate No.
Strahlerhalter - Nr.	5746	Source Holder No.

Der oben genannte Strahler wurde auf Dichtheit und Kontamination geprüft und als dicht befunden.

The mentioned source has been tested for leakage and contamination. The source has been found tight.

Die Oberfläche des Strahlers ist kontaminationsfrei. Die Prüfung wurde vom Hersteller in unserem Namen durchgeführt.

The surface is free of contamination. The test has been performed by the manufacturer in our name.

Oberflächenkontam. (Wischprüfung)	< 185 Bq/ < 5nCi 13.DEZ.00	Surface contamination (wipe test)
Dichtheitsprüfung (Blasentest)	leak free 13.DEZ.00	Leakage (hot liquid bubble test)

Der o.g. Strahler ist in einem neuen bzw. überprüften und zugelassenen Strahlerhalter eingebaut.

A.m. source has been built into a new or examined and approved source holder.

MDS Nordion Haan GmbH

09.01.01 .... i.A. [signature] ....

Datum / Date Unterschrift / Signature

D Irradiation documentation

Irradiation Test Documentation

Fraunhofer INT

Irradiation Source	Gammamet TK100	Date	2011-08-21
Responsible Employee	Kündgen	Temperature	24°C
Project Description	IS49		

Reference Data for Dose Rate Calculation

Refernce Dose Rate	0.01974 Gy/s ± ***2.5%***	Standard uncertainty[1]
Reference Distance	10 cm ± ***0.5%***	Standard uncertainty[1]
Reference Date	1990-01-01	

Geometry of Irradiated Object (As defined or measured):

Inner Diameter	6.55 cm ± ***0.05*** cm	Standard uncertainty[1]
Outer Diameter	7.86 cm ± ***0.05*** cm	Standard uncertainty[1]
Height	0.18 cm ± ***0.05*** cm	Standard uncertainty[1]

Distances of Point Source:

Surface of Object	11.07 cm ± ***0.05*** cm	Standard uncertainty[1]
Object Minimum	11.53 cm ± 0.05 cm	Standard uncertainty[2]
Object Maximum	11.93 cm ± 0.07 cm	Standard uncertainty[2]
Mean Distance	**11.73 cm ± 0.11 cm**	*Expanded uncertainty[3]*

Dose Rates in Object

Minimum	0.0008 Gy/s ± 2.9%	Standard uncertainty[2]
Mean	**0.0008 Gy/s ± 2.8%**	Standard uncertainty[2]
Maximum	0.0009 Gy/s ± 2.8%	Standard uncertainty[2]

Irradiation Time	**1220768 s** ± ***1*** **s**	Standard uncertainty[1]
in DD HH:MM:SS	14 03:06:08 ± *1* s	Standard uncertainty[1]

Dose in Object

Minimum	976 Gy ± 2.9%	Standard uncertainty[2]
Maximum	1045 Gy ± 2.8%	Standard uncertainty[2]
Mean	**1010 Gy ± 5.7%**	*Expanded uncertainty[3]*
Homogeneity	6.8%	

[1] Experience or statistics based estimation of standard uncertainty with a coverage factor k=1

[2] Combined standard uncertainty with a coverage factor k=1

[3] Determined from a combined standard uncertainty (i.e., estimated standard deviations of values above) and a coverage factor k = 2. Since it can be assumed that the possible estimated values of the dose are approximately normally distributed with approximate standard deviation, the unknown value of the dose is believed to lie in the interval given with a level of confidence of approximately 95 %.

Standard Irradiation Test Documentation Sheet, 2011-08-30

E RVT-TES-11/025/STO, Issue B

TESAT SPACECOM Project: Z	IRRADIATION TEST PLAN NO.: RVT-TES-11/025/STO	Page:1 of 2 Issue: B Date: 03.08.2010
Part Number: IS49 **Package:** LCC-6	**Component Designation:** IS49 **Category:** Opto-coupler	**Specification** Generic: MIL-PRF-19500 Test: RA.1801.021.10 **1)**
Manufacturer: Isocom, UK	**Date Code:** 1018 **Wafer Lot** LED: 14B08030-11J3821D0 PD: 14B09050-8460956050	**Originator:** Name: Storm Telephone: ++49 7191 930 1446

Radiation Source:	**Test Facility:**	**Exposure**	**Annealing Test:**
Co60	F-INT	Single: --- Multiple: X	No: Yes: Y **2)**

Parts Identification	
Control Size: 1	S/N: #1
Irradiated Samples Size: 10	
ON-Mode Sample Size: 5	S/N: #2, 3, 4, 5, 6
OFF-Mode Sample Size: 5	S/N: #7, 8, 9, 10, 11

Irradiation Steps							
Single Exposure **- not applicable -**	Multiple Exposure						
Dose [KRad (Si)]:	Irradiation Step	1	2	3	4	5	
Dose Rate [KRad (Si)/hr]:	accumulated Dose [KRad (Si)]:	10	25	50	75	100	
Exposure Time:	Dose Rate [KRad (Si)/hr]: **3)**	0.3					

Electrical Measurements			
Parameter 4)	**Symbol**	**Condition 5)**	**Limits (Post RAD)**
Diode Forward Voltage	V_F	$I_F = 10.0$ mA	1.4 ... 1.46 V
Diode Reverse Current	I_R	$V_R = 2.0$ V	< 100 µA
Collector Emitter Leakage Curent	$I_{C(leak)}$	$V_{CE} = 40$ V	< 1.0 mA
Collector Emitter Dark Current	I_{CEO}	$V_{CE} = 20$ V, $I_F = 0$	< 100 nA
Collector Current A	I_{Ca}	$V_{CE} = 1$ V, $I_F = 1.0$ mA	> 4.0 mA
Collector Current B	I_{Cb}	$V_{CE} = 1$ V, $I_F = 15.0$ mA	> 15 mA
Collector Current C	I_{Cc}	$V_{CE} = 5$ V, $I_F = 10.0$ mA **6)**	> 35 mA
Collector Current D	I_{Cd}	$V_{CE} = 5$ V, $I_F = 15.0$ mA **6)**	> 15 mA
Collector Current E	I_{Ce}	$V_{CE} = 15$ V, $I_F = 1.0$ mA	> 5.0 mA)
Collector Emitter Saturation Voltage	$V_{CE(sat)}$	$I_C = 10.0$ mA, $I_F = 20.0$ mA	< 0.22 V

Notes:

General: The test shall be conducted in line with ESA basic specification ESCC 22900

1) Test specification is targeted for a CSM 100 device, but is also applicable for IS49 test samples.
2) Annealing shall be performed as specified in para 1 of this document
3) The recommended dose rate shall be 0.3 KRad (Si) / hr. On the whole the dose rate may be selectable according to para 4.3 of ESA/SCC22900, low dose rate window (0.036 to 0.36 KRad/hr).
4) Parameters listed shall be tested before and after each radiation step and each annealing step.
5) Conditions as defined in Table 4-1 of test specification.
6) Pulse Condition as defined in Table 4-1 of test specification.

RVT-TES-11/025/STO Iss.B page 1

1. Annealing

An annealing will be performed in two steps:

step 1

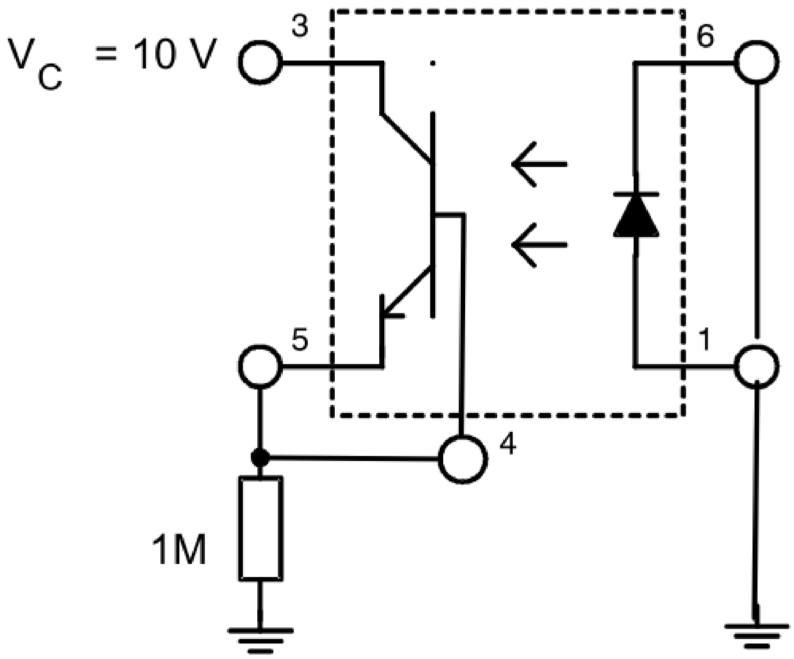
24 hrs anneal at room temperature with applied bias and subsequent electrical measurement.

step 2

168 hrs anneal at100°C with applied bias and subsequent electrical measurement.

2. Circuit during Irradiation and Annealing

2.1 ON-Mode



2.2 OFF Mode

All pins shall be short circuited (5 Opto-couplers).

3. Electrical Measurements.

The Electrical Measurements shall be performed at room temperature. The measurements shall be performed before irradiation, after each irradiation step and after each annealing period.

0 hr electrical measurements shall be counted as a failure, if limits of Table 4-1 of test specification are exceeded.

4. Documentation.

All measurements shall be performed as read and record. Every parameter shall be in addition shown in a x/y graph, which shows the dependence of the measured value (= y) from the measurement points (0hrs, after each irradiation step, after first and second anneal = x).
A test report shall be prepared on paper and electronic media (pdf file) including parts reference, dosimetry and irradiation facility description, applied dose rate and dose level, description of test equipment, bias condition and test story.
Additionally to the test report, the test results on the measured parameters shall be provided in a tabular scheme in an Excel format, to be delivered on CDROM or by email.