Fraunhofer-Institut
für Naturwissenschaftlich-Technische Trendanalysen (INT)

Appelsgarten 2, 53879 Euskirchen, Telefon: 0 22 51/18-0, Fax: 0 22 51/18-2 77, E-Mail: info@int.fraunhofer.de

Arbeitsbericht **71/2011**
Dezember 2011

Neutron Irradiation of Electronic Components

Optocoupler IS49

Manufacturer: Isocom, UK

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

S. Metzger, P. Clemens, T. Kündgen,
W. Lennartz und U. Weber

Abstract

This report presents results of 14 MeV neutron irradiation tests on optocouplers IS49 from Isocom, UK, performed at the Fraunhofer INT. The samples were provided by Tesat Spacecom GmbH. All devices were functional after a displacement damage equivalent 1 MeV fluence of 1.0×10^{12} cm^{-2} but some parameters were outside the given limits.

Fraunhofer INT

Contents

List of Figures

List of Tables

1 Introduction and Summary

The Fraunhofer Institute for Technical Trend Analysis (INT) carried out a series of 14 MeV neutron irradiations on optocouplers IS49 on 2011-08-24 for Tesat Spacecom GmbH (Tesat). The test plan was based on the ESA Basic Specification No. 22900 in general and on Tesat's irradiation test plan *RVT-TES-11/026/STO issue B* in particular.

1. **All devices were functional after a total 1 MeV equivalent neutron fluence of 1.0 x 10^{12} cm^{-2}.**

2. **All but two parameters were inside the given limits.**

3. **Collector current A was below the lower limit after 5.1 x 10^{11} and collector current E after 2.1 x 10^{11} 1 MeV neutrons per cm^2.**

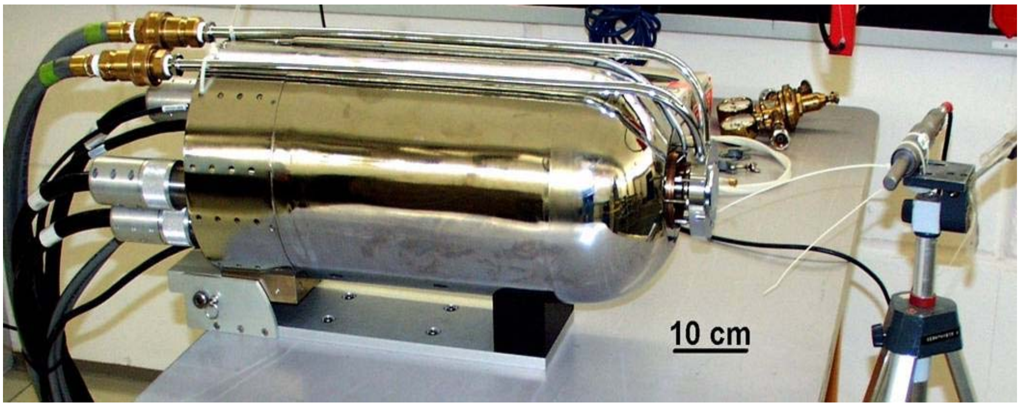
4. **Devices operated in the on- or off-mode during irradiation behaved similar during neutron irradiation.**

2 Test Conditions

2.1 Neutron Source

The devices under test (DUT) were irradiated with 14 MeV neutrons at the THERMO-Fisher D-711 neutron generator of the Fraunhofer-INT (see figure 1). This generator accelerate deuterium ions (D = H-2) with typical voltages of 150 kV (maximum 200 kV). These nuclei are focused and hit onto deuterium or tritium targets (T = H-3). Inside the target D-D or D-T fusion reaction are stimulated which produce helium isotopes (He-3 or He-4) and fast neutrons with energies of 2.5 MeV (for D-D reactions) or 14 MeV (in the case of D-T reactions).

Figure 1:
D-711 neutron generator at the Fraunhofer-INT



At a typical acceleration voltage of 150 kV and near the maximum current of about 2.5 mA up to 3×10^{10} neutrons/s in 4π-steradian can be produced with a new tritium target. Based upon the fact that the energy of the neutrons (14 MeV) is much larger than the kinetic energy of the deuterium ions (≈ 150 keV) the emission is nearly isotropic and the intensity falls off as $1/R^2$ with R being the distance from the tritium target which can be as small as ca. 1 cm. Even at such short distances the emission can be approximated as being isotropic with high certainty because the emission point has a very small diameter (ca. 2 mm[1]).

[1] Private communication by the manufacturer.

2.2 Irradiation Conditions

The devices were mounted on two different bias board (on- and off-mode DUTs were irradiated separately) at a distance of about 2.3[2] cm from the neutron emission point (see figure 2 and 3). The neutron flux was monitored online during irradiation with a calibrated[3] uranium fission chamber FC165/402 (see figure 4) at a fixed distance of 100 cm to the source point (this is standard for all neutron irradiation at the D711). An additional fission chamber was mounted on the PCB.

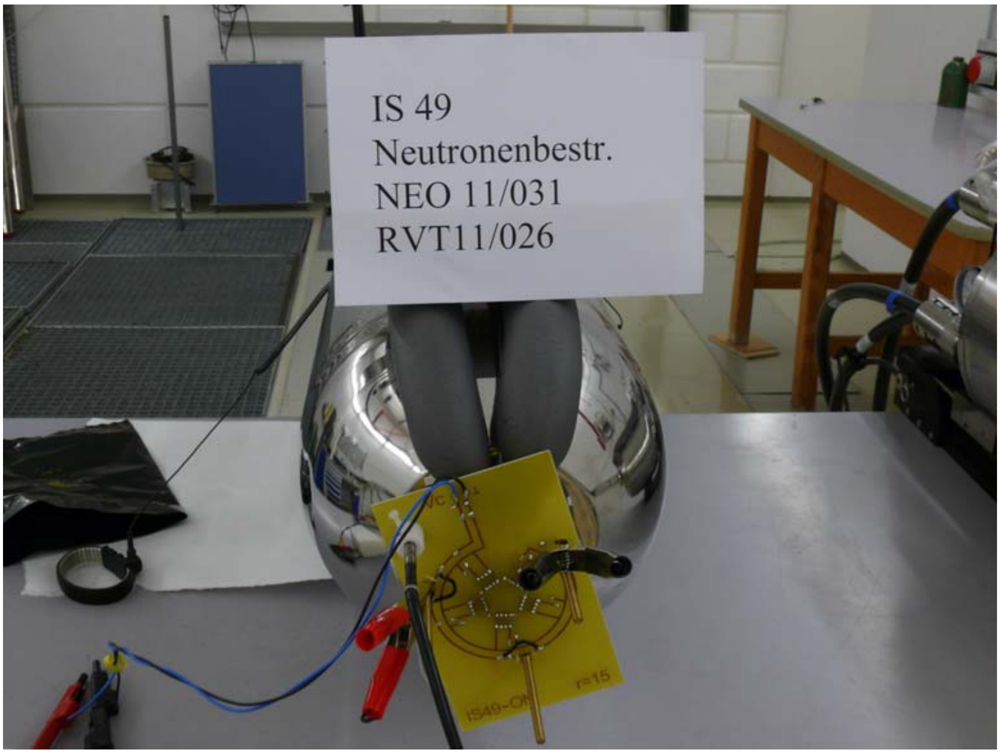
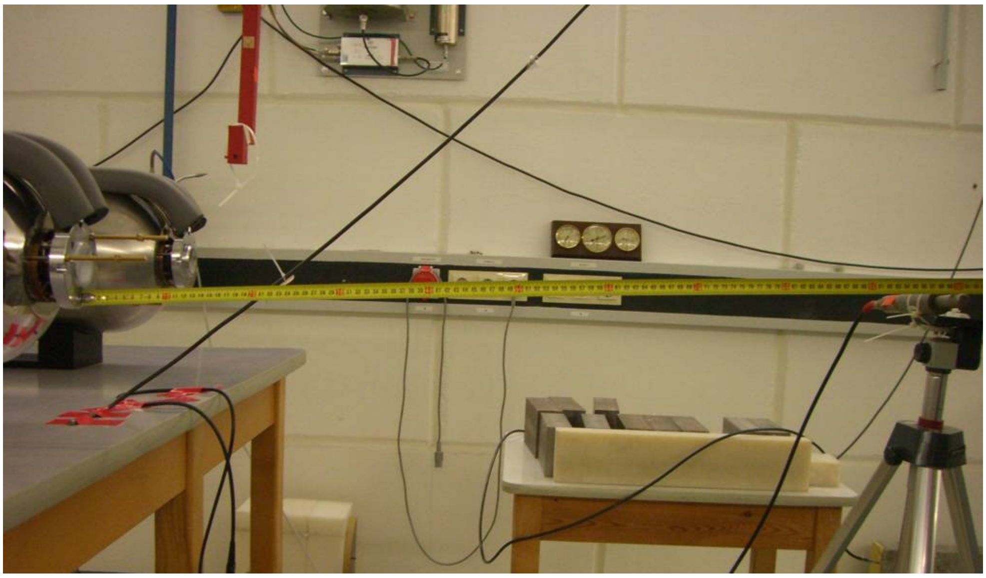


Figure 2: Irradiation setup at the D711 for the neutron test of IS49 on 2011-08-24. Here On-Mode devices.

[2] 2.3 cm comes from 1 cm distance inside the target head plus .67 cm normal distance as can be seen in figure 2 and a radius of 1.5 cm on the PCB.

[3] H.G. Bengel, W. Lennartz, A. Rosenstock, W. Rosenstock and J. Schulze, "Neutronenflußmessung mit Aktivierungsfolien und Spaltkammern", Fraunhofer INT, Report No. 128, July 1987.

Figure 3:
Uranium fission chamber FC165/402 used for online dosimetry at a distance of 1 m.



The course of the irradiation test is shown in the following table 1. On- and Off-mode devices were irradiated separately but measured as soon as their particular irradiation was finished. So there is only one measurement per irradiation step mentioned.

Table 1: Times and actions during the irradiation of the IS49 on 2011-08-24.

Start	End	Duration [min]	Action
08:36	09:45	69	Pre-Irradiation Measurement
10:25	10:28	3	1st Irradiation On-Mode Devices
10:54	10:58	4	1st Irradiation Off-Mode Devices
10:50	11:35	45	1st Measurement
11:27	11:31	4	2nd Irradiation On-Mode Devices
11:52	11:55	3	2nd Irradiation Off-Mode Devices
11:47	12:28	41	2nd Measurement
12:18	12:27	9	3rd Irradiation On-Mode Devices
13:10	13:19	9	3rd Irradiation Off-Mode Devices
13:12	13:50	38	3rd Measurement
13:44	13:54	10	4th Irradiation On-Mode Devices
14:19	14:28	9	4th Irradiation Off-Mode Devices
14:13	15:03	50	4th Measurement

In the following the 14 MeV neutron fluence measured at 100 cm distance with the fission chamber is used to calculate the fluence at the distance of the DUTs. As the neutron emission falls off with the square root of the distance (emission is nearly isotropic) one can calculate the fluence at 2.3 cm according to equation (1):

fluence @ 2.3 cm = fluence @ 100 cm * (100 cm / 2.3 cm)^2 (1)

The derived fluences are summarized in table 3 hereafter. The uncertainty of these values is ca. 25 percent (the uncertainty of the calibration of the fission chamber is 3.5 %, the accuracy of the distances is ca. 0.2 cm and the deviation of the neutron emission from isotropy is less than 5 %).

Table 2: Measured and calculated 14 MeV neutron fluences during the irradiation of the IS49.

Device Type	Counts in FC165	14 MeV Neutron Step Fluence @ 1 m [cm^{-2}]	14 MeV Neutron Step Fluence @ 2.3 cm [cm^{-2}]
Off-Mode Devices	12770	2.98E+07	5.87E+10
	12486	2.92E+07	5.74E+10
	36471	8.52E+07	1.68E+11
	61129	1.43E+08	2.81E+11
On-Mode Devices	12513	2.92E+07	5.75E+10
	12331	2.88E+07	5.67E+10
	37116	8.67E+07	1.71E+11
	61335	1.43E+08	2.82E+11

The temperature during irradiation stayed within 24 ± 2 °C inside the irradiation room.

During the irradiation five out of ten DUTs were biased according to figure 1 of RVT-TES-11/026/STO (see annex 1), i.e. on-mode. The rest was irradiated with all pins short circuited and grounded, i.e. off-mode.

2.3 1 MeV Equivalent Neutron Fluence

The requested fluence was 1 x 10^{12} cm^{-2} 1 MeV neutron equivalent fluence.

It has been shown that displacement damage can be simulated for any particular type of radiation by using the value of non-ionization energy loss (NIEL). This fact implies that the effects of the displacements are only proportional to the NIEL and do not depend on the nature of the displacements[4]. For particles of sufficient energy to cause displacement damage, the quantity of interest is the particle fluence (particles/cm^2).

Tabulations of NIEL values with respect to target materials, particle types and energies the authors of [7] can be used to calculate the 1 MeV neutron equivalent fluence for 14 MeV neutrons[5]. Vasilescu and Lindstroem give a value of 1.8 as the conversion factor in Silicon, which means that one 14 MeV neutron produces 1.8 times more displacements than a 1 MeV neutron in Silicon. So the calculated 1 MeV fluences at the position of the DUTs are presented in table 3.

Table 3: Calculated displacement damage equivalent 1 MeV neutron fluences for the irradiation of the IS49.

14 MeV Neutron Step Fluence @ 2.3 cm [cm^{-2}]	DD-equiv. 1 MeV Neutron Step Fluence @ 2.3 cm [cm^{-2}]	DD-equiv. 1 MeV Total Neutron Fluence @ 2.3 cm [cm^{-2}]
5.87E+10	1.06E+11	1.06E+11
5.74E+10	1.03E+11	2.09E+11
1.68E+11	3.02E+11	5.11E+11
2.81E+11	5.06E+11	1.02E+12
5.75E+10	1.03E+11	1.03E+11
5.67E+10	1.02E+11	2.05E+11
1.71E+11	3.07E+11	5.12E+11
2.82E+11	5.07E+11	1.02E+12

4 G.P. Summers, E.A. Burke, P. Shapiro, S.R. Messenger and R.J. Walters, "Damage correlation in semiconductors exposed to gamma, electron and proton irradiations", IEEE Trans Nucl. Sci, Vol. 40, pp 1372-1379, Dec 1993.

5 A. Vasilescu (INPE Bucharest) and G. Lindstroem (University of Hamburg), "Displacement damage in silicon, on-line compilation" http://sesam.desy.de/members/gunnar/Si-dfuncs.html.

2.4 Electrical Measurements

The measured electrical parameters are listed in **Table 4**

Table 4: Measured electrical parameters

Ref No.	Parameter	Symbol
1	Diode Forward Voltage	V_F
2	Diode Reverse Current	I_R
3	Collector-Emitter Leakage Current	$I_{C(leak)}$
4	Collector-Emitter Dark Current	I_{CEO}
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	Collector-Emitter Saturation Voltage	$V_{CE(sat)}$

The electrical measurements were performed with a HP 4155B Parameter Analyser.

Before Irradiation all DUTs were inside the allowed limits during the initial electrical characterization.

All electrical measurements were done at room temperature of 22.5 ± 1 °C.

2.5 Sample Identification

The part number was **IS49**.

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

The manufacturer was **Isocom, UK**.

The date code of the DUTs was **1018** and
the wafer lot
of the LED: **14B08030-11J3821D0** and
of the PD: **14B09050-8460956050**.

The DUTs in the "On-Mode" had the serial numbers:
35, 36, 37, 38 and **39**.

The "Off-Mode" devices were nos.:
40, 41, 42, 43 and **44**.

The reference device during the test was no. **34**.

2.6 Comments

- The serial numbers of the actual delivered devices were different than those listed in the RVT.
- No annealing or accelerated ageing was performed.

3 Measurement Results

3.1 Diode Forward Voltage

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

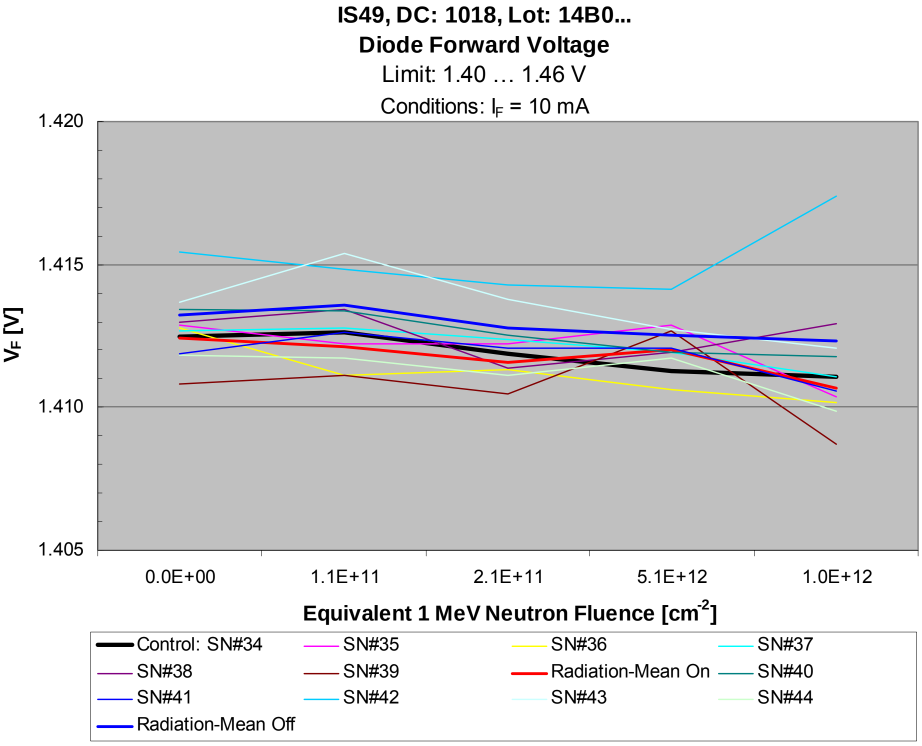
PD: 14B09050- 8460956050

ON-Mode	**Equivalent 1 MeV Neutron Fluence [cm^{-2}]**				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#35	1.4129	1.4122	1.4122	1.4129	1.4104
SN#36	1.4128	1.4111	1.4113	1.4106	1.4102
SN#37	1.4127	1.4128	1.4124	1.4119	1.4111
SN#38	1.4130	1.4134	1.4114	1.4119	1.4129
SN#39	1.4108	1.4111	1.4105	1.4127	1.4087
Radiation-Mean On	**1.4124**	**1.4121**	**1.4116**	**1.4120**	**1.4106**
Standarddeviation	**0.0009**	**0.0010**	**0.0008**	**0.0009**	**0.0015**
Control: SN#34	1.4125	1.4126	1.4119	1.4113	1.4111

OFF-Mode	**Equivalent 1 MeV Neutron Fluence [cm^{-2}]**				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#40	1.4134	1.4134	1.4125	1.4119	1.4118
SN#41	1.4119	1.4126	1.4121	1.4121	1.4106
SN#42	1.4154	1.4148	1.4143	1.4141	1.4174
SN#43	1.4137	1.4154	1.4138	1.4127	1.4121
SN#44	1.4118	1.4117	1.4111	1.4117	1.4099
Radiation-Mean Off	**1.4132**	**1.4136**	**1.4128**	**1.4125**	**1.4123**
Standarddeviation	**0.0015**	**0.0015**	**0.0013**	**0.0010**	**0.0030**
Control: SN#34	1.4125	1.4126	1.4119	1.4113	1.4111

Table 5: Diode Forward Voltage

Figure 4: V_F


IS49, DC: 1018, Lot: 14B0...
Diode Forward Voltage
Limit: 1.40 … 1.46 V
Conditions: I_F = 10 mA
1.420
1.415
1.410
1.405
V_F [V]
0.0E+00
1.1E+11
2.1E+11
5.1E+12
1.0E+12
Equivalent 1 MeV Neutron Fluence [cm^-2]
Control: SN#34
SN#35
SN#36
SN#37
SN#38
SN#39
Radiation-Mean On
SN#40
SN#41
SN#42
SN#43
SN#44
Radiation-Mean Off

3.2 Diode Reverse Current

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

Conditions: V_R = 2 V Date Code: 1018

Limit: < 100 µA Lot:

Accuracy: -- LED: 14B08030- 11J3821D0

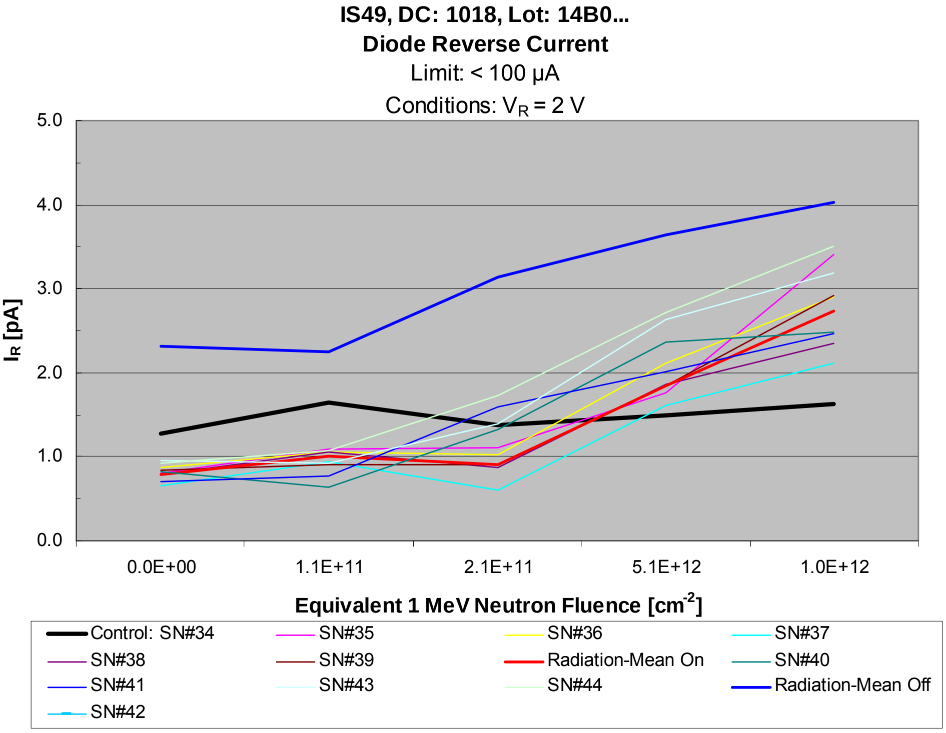
PD: 14B09050- 8460956050

ON-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#35	0.8000	1.0900	1.1000	1.7700	3.4100
SN#36	0.8700	1.0600	1.0300	2.1200	2.9100
SN#37	0.6600	0.9400	0.6100	1.6100	2.1200
SN#38	0.7900	1.0500	0.8800	1.8700	2.3500
SN#39	0.8400	0.9100	0.9100	1.8500	2.9200
Radiation-Mean On	**0.7920**	**1.0100**	**0.9060**	**1.8440**	**2.7420**
Standarddeviation	**0.0804**	**0.0797**	**0.1880**	**0.1851**	**0.5115**
Control: SN#34	1.2700	1.6400	1.3700	1.5000	1.6300

OFF-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#40	0.8200	0.6400	1.3200	2.3600	2.4800
SN#41	0.7100	0.7800	1.5900	2.0100	2.4600
SN#42	8.1500	7.7900	9.6500	8.5200	8.5000
SN#43	0.9500	0.9300	1.4000	2.6300	3.1900
SN#44	0.9300	1.0800	1.7200	2.7100	3.5100
Radiation-Mean Off	**2.3120**	**2.2440**	**3.1360**	**3.6460**	**4.0280**
Standarddeviation	**3.2650**	**3.1047**	**3.6448**	**2.7384**	**2.5409**
Control: SN#34	1.2700	1.6400	1.3700	1.5000	1.6300

Table 6: Diode Reverse Current

Figure 5: I_R



IS49, DC: 1018, Lot: 14B0...
Diode Reverse Current
Limit: < 100 µA
Conditions: V_R = 2 V
5.0
4.0
3.0
2.0
1.0
0.0
I_R [pA]
0.0E+00
1.1E+11
2.1E+11
5.1E+12
1.0E+12
Equivalent 1 MeV Neutron Fluence [cm^-2]
Control: SN#34
SN#35
SN#36
SN#37
SN#38
SN#39
Radiation-Mean On
SN#40
SN#41
SN#43
SN#44
Radiation-Mean Off
SN#42

3.3 Collector-Emitter Leakage Current

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

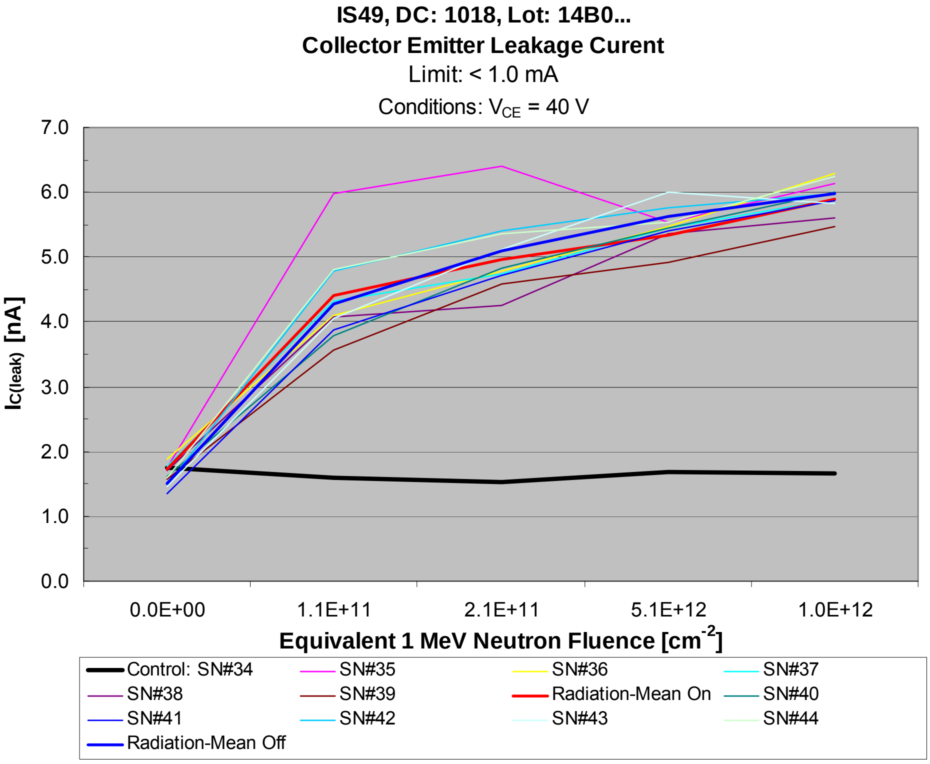
PD: 14B09050- 8460956050

ON-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#35	1.7472	5.9850	6.4030	5.5420	6.1470
SN#36	1.8821	4.1020	4.7750	5.4610	6.2900
SN#37	1.7637	4.3230	4.7500	5.4460	5.9000
SN#38	1.7112	4.0750	4.2640	5.3510	5.6080
SN#39	1.5745	3.5650	4.5950	4.9220	5.4800
Radiation-Mean On	**1.7357**	**4.4100**	**4.9574**	**5.3444**	**5.8850**
Standarddeviation	**0.1106**	**0.9232**	**0.8334**	**0.2457**	**0.3441**
Control: SN#34	1.7555	1.5964	1.5335	1.6807	1.6671

OFF-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#40	1.6141	3.7980	4.8390	5.4400	5.9930
SN#41	1.3591	3.8850	4.7150	5.4080	5.8730
SN#42	1.4825	4.7810	5.4100	5.7610	5.9850
SN#43	1.4513	4.0570	5.1180	6.0070	5.8230
SN#44	1.5861	4.8070	5.3560	5.5430	6.2370
Radiation-Mean Off	**1.4986**	**4.2656**	**5.0876**	**5.6318**	**5.9822**
Standarddeviation	**0.1036**	**0.4914**	**0.3072**	**0.2511**	**0.1599**
Control: SN#34	1.7555	1.5964	1.5335	1.6807	1.6671

Table 7: Collector-Emitter Leakage Current

Figure 6: $I_{C(leak)}$



3.4 Collector-Emitter Dark Current

Collector-Emitter Dark 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

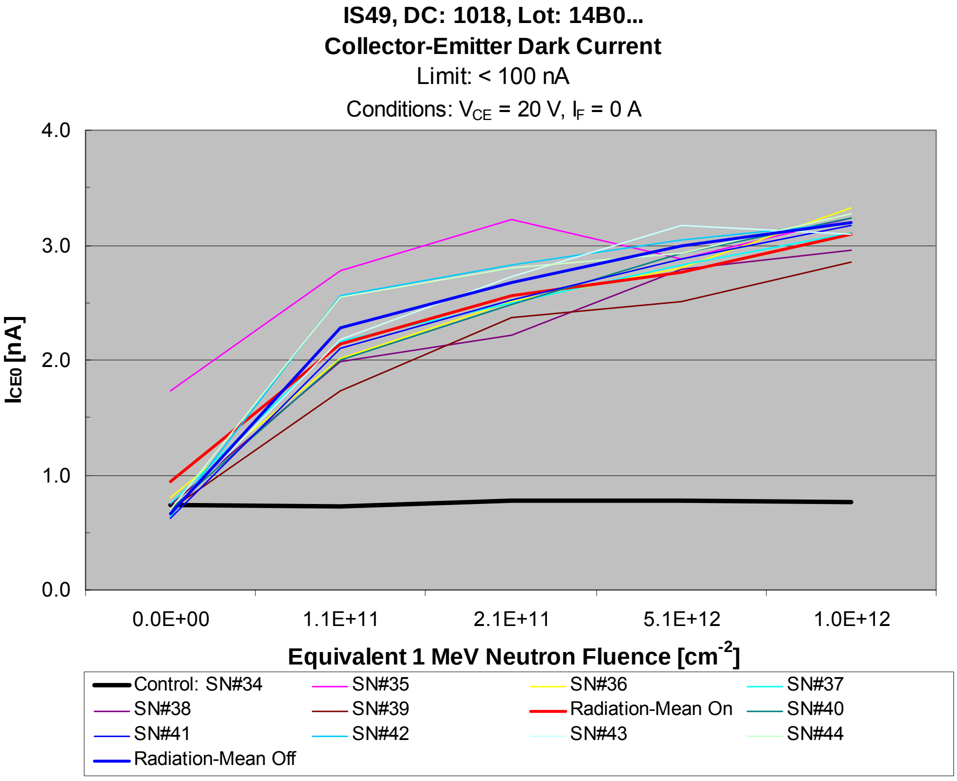
PD: 14B09050- 8460956050

ON-Mode	**Equivalent 1 MeV Neutron Fluence [cm^{-2}]**				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#35	1.7360	2.7820	3.2170	2.8760	3.2350
SN#36	0.8080	2.0160	2.5150	2.8040	3.3230
SN#37	0.7460	2.1600	2.4920	2.8250	3.1140
SN#38	0.7440	1.9890	2.2130	2.7950	2.9590
SN#39	0.6960	1.7350	2.3640	2.5050	2.8500
Radiation-Mean On	**0.9460**	**2.1364**	**2.5602**	**2.7610**	**3.0962**
Standarddeviation	**0.4434**	**0.3920**	**0.3864**	**0.1465**	**0.1939**
Control: SN#34	0.7330	0.7230	0.7810	0.7730	0.7630

OFF-Mode	**Equivalent 1 MeV Neutron Fluence [cm^{-2}]**				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#40	0.7020	1.9990	2.4870	2.9280	3.2340
SN#41	0.6220	2.1040	2.5210	2.8750	3.1730
SN#42	0.6330	2.5570	2.8310	3.0470	3.1990
SN#43	0.6780	2.1770	2.7280	3.1690	3.0950
SN#44	0.7000	2.5490	2.8020	2.9310	3.2762
Radiation-Mean Off	**0.6670**	**2.2772**	**2.6738**	**2.9900**	**3.1954**
Standarddeviation	**0.0375**	**0.2596**	**0.1599**	**0.1182**	**0.0682**
Control: SN#34	0.7330	0.7230	0.7810	0.7730	0.7630

Table 8: Collector-Emitter Dark Current

Figure 7: I_{CEO}



3.5 Collector Current A

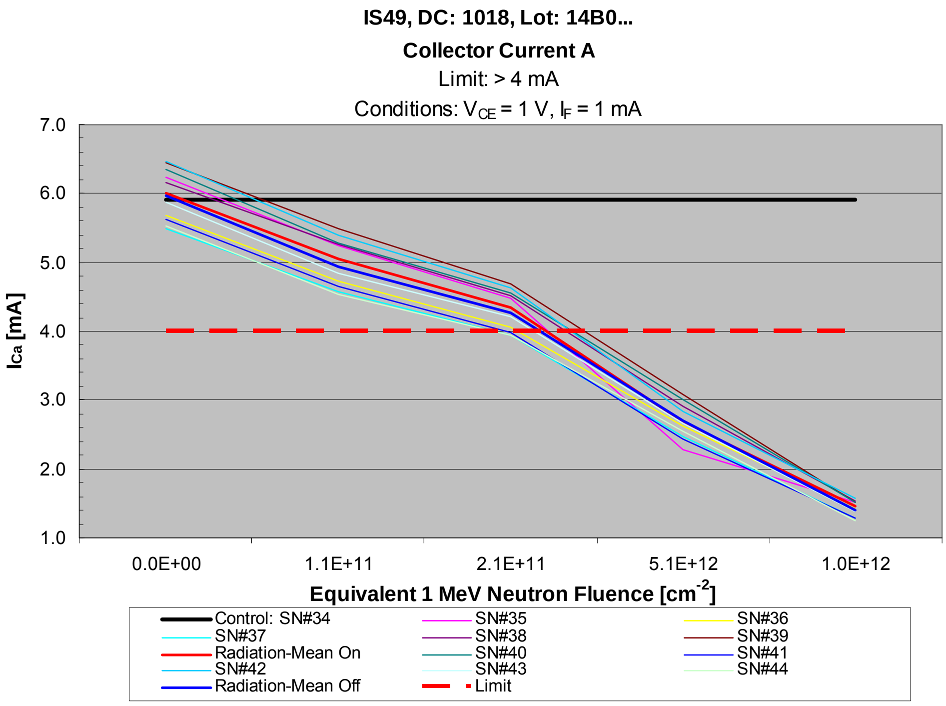
Collector Current A I_{Ca} [mA] **IS49**
Conditions: V_{CE} = 1 V, I_F = 1 mA Date Code: 1018
Limit: > 4 mA Lot:
Accuracy: -- LED: 14B08030- 11J3821D0
PD: 14B09050- 8460956050

ON-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#35	6.2340	5.2460	4.4860	2.2790	1.5070
SN#36	5.6720	4.7220	4.0530	2.6260	1.4240
SN#37	5.4920	4.5790	3.9450	2.4750	1.2840
SN#38	6.1610	5.2550	4.5140	2.9030	1.5270
SN#39	6.4510	5.4950	4.6840	3.0780	1.5180
Radiation-Mean On	**6.0020**	**5.0594**	**4.3364**	**2.6722**	**1.4520**
Standarddeviation	**0.4030**	**0.3897**	**0.3195**	**0.3215**	**0.1025**
Control: SN#34	5.9140	5.9200	5.9160	5.9190	5.9170

OFF-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#40	6.3420	5.2720	4.5570	3.0020	1.5210
SN#41	5.6330	4.6540	3.9740	2.4320	1.2810
SN#42	6.4740	5.3940	4.6320	2.8360	1.5710
SN#43	5.8700	4.8410	4.2100	2.6650	1.3750
SN#44	5.5320	4.5430	3.9380	2.5470	1.2440
Radiation-Mean Off	**5.9702**	**4.9408**	**4.2622**	**2.6964**	**1.3984**
Standarddeviation	**0.4207**	**0.3760**	**0.3219**	**0.2270**	**0.1440**
Control: SN#34	5.9140	5.9200	5.9160	5.9190	5.9170

Table 9: Collector Current A

Figure 8: I_{Ca}



IS49, DC: 1018, Lot: 14B0...
Collector Current A
Limit: > 4 mA
Conditions: V_CE = 1 V, I_F = 1 mA
7.0
6.0
5.0
4.0
3.0
2.0
1.0
Ica [mA]
0.0E+00
1.1E+11
2.1E+11
5.1E+12
1.0E+12
Equivalent 1 MeV Neutron Fluence [cm^-2]
Control: SN#34
SN#35
SN#36
SN#37
SN#38
SN#39
Radiation-Mean On
SN#40
SN#41
SN#42
SN#43
SN#44
Radiation-Mean Off
Limit

3.6 Collector Current B

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

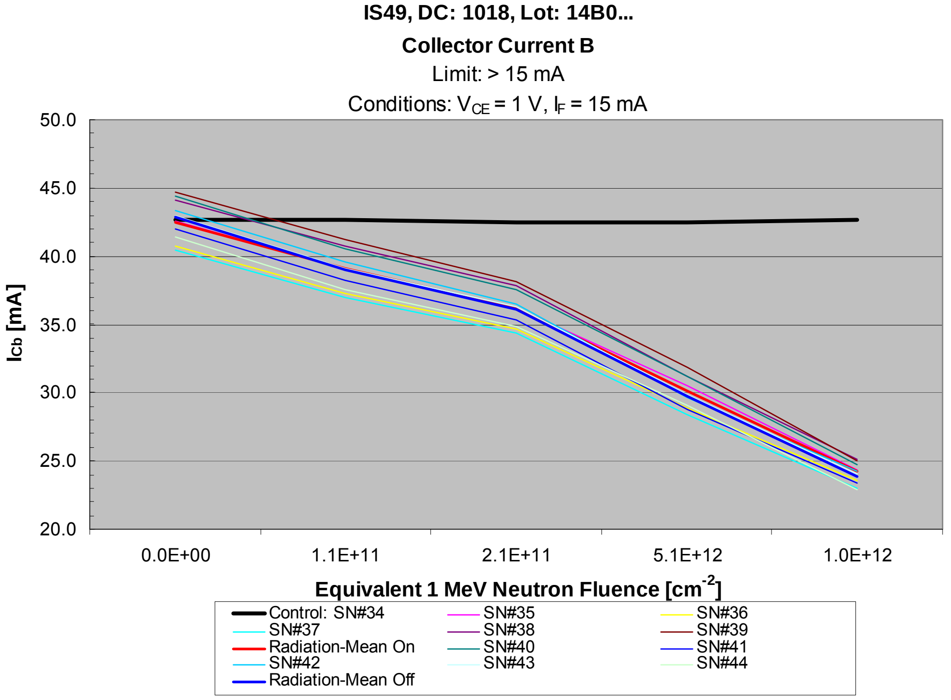
PD: 14B09050- 8460956050

ON-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#35	42.5890	39.0690	36.1720	30.5040	24.3500
SN#36	40.7600	37.2680	34.6410	28.8900	23.5340
SN#37	40.4680	37.0140	34.4040	28.3590	22.9530
SN#38	44.0900	40.7070	37.8410	31.2120	25.1230
SN#39	44.6890	41.2400	38.1490	31.8460	25.0350
Radiation-Mean On	**42.5192**	**39.0596**	**36.2414**	**30.1622**	**24.1990**
Standarddeviation	**1.9028**	**1.9276**	**1.7421**	**1.4937**	**0.9448**
Control: SN#34	42.6780	42.7000	42.4470	42.4490	42.6390

OFF-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#40	44.3870	40.5390	37.5710	31.2230	24.7180
SN#41	42.0190	38.2740	35.2960	28.7980	23.3590
SN#42	43.3710	39.5770	36.5160	29.6870	24.2850
SN#43	42.9510	39.1070	36.3230	29.8530	24.0240
SN#44	41.3950	37.5580	34.8440	29.0360	22.9340
Radiation-Mean Off	**42.8246**	**39.0110**	**36.1100**	**29.7194**	**23.8640**
Standarddeviation	**1.1671**	**1.1531**	**1.0736**	**0.9481**	**0.7163**
Control: SN#34	42.6780	42.7000	42.4470	42.4490	42.6390

Table 10: Collector Current B

Figure 9: I_{Cb}


IS49, DC: 1018, Lot: 14B0...
Collector Current B
Limit: > 15 mA
Conditions: V_{CE} = 1 V, I_F = 15 mA
50.0
45.0
40.0
35.0
30.0
25.0
20.0
ICb [mA]
0.0E+00
1.1E+11
2.1E+11
5.1E+12
1.0E+12
Equivalent 1 MeV Neutron Fluence [cm^{-2}]
Control: SN#34
SN#35
SN#36
SN#37
SN#38
SN#39
Radiation-Mean On
SN#40
SN#41
SN#42
SN#43
SN#44
Radiation-Mean Off

3.7 Collector Current C

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

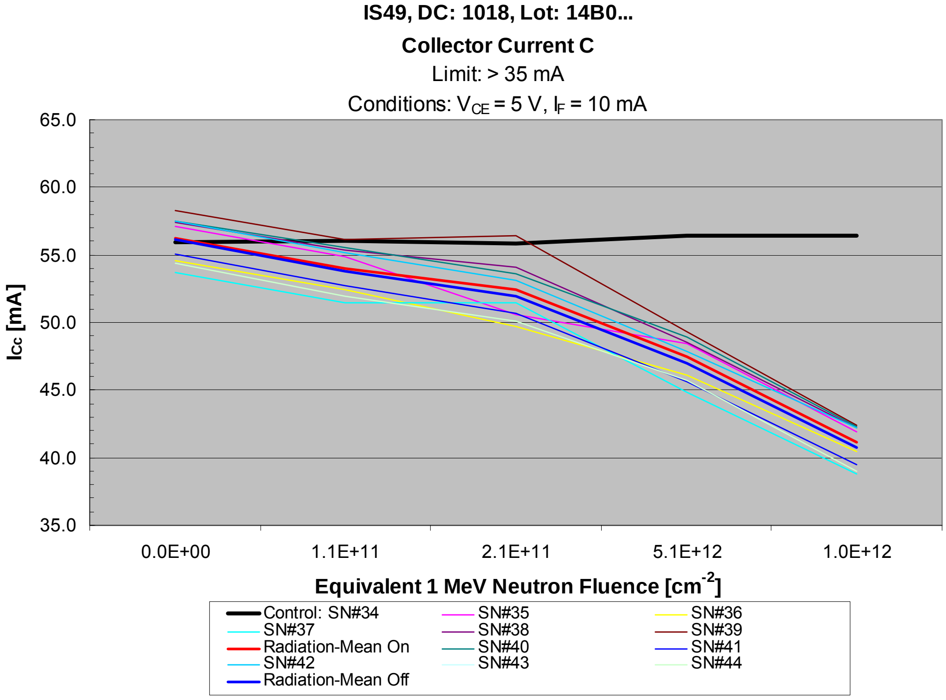
PD: 14B09050- 8460956050

ON-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#35	57.0670	54.8510	50.6040	48.4630	41.9140
SN#36	54.5800	52.4000	49.6660	46.0810	40.4120
SN#37	53.6790	51.4580	51.4140	44.8310	38.7680
SN#38	57.4120	55.3340	54.0620	48.4910	42.2520
SN#39	58.2360	56.1010	56.4340	49.3210	42.4270
Radiation-Mean On	**56.1948**	**54.0288**	**52.4360**	**47.4374**	**41.1546**
Standarddeviation	**1.9587**	**1.9960**	**2.7704**	**1.8936**	**1.5530**
Control: SN#34	55.9640	56.0150	55.8910	56.4090	56.3910

OFF-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#40	57.4770	55.5380	53.5920	48.9290	42.3090
SN#41	55.0850	52.7510	50.7130	45.6310	39.4780
SN#42	57.4840	55.1410	53.1410	47.8180	42.2450
SN#43	56.1820	53.7790	51.9420	47.0190	40.7210
SN#44	54.3740	51.9810	50.1420	45.6670	39.0080
Radiation-Mean Off	**56.1204**	**53.8380**	**51.9060**	**47.0128**	**40.7522**
Standarddeviation	**1.3987**	**1.5183**	**1.4920**	**1.4178**	**1.5263**
Control: SN#34	55.9640	56.0150	55.8910	56.4090	56.3910

Table 11: Collector Current C

Figure 10: I_{Cc}



3.8 Collector Current D

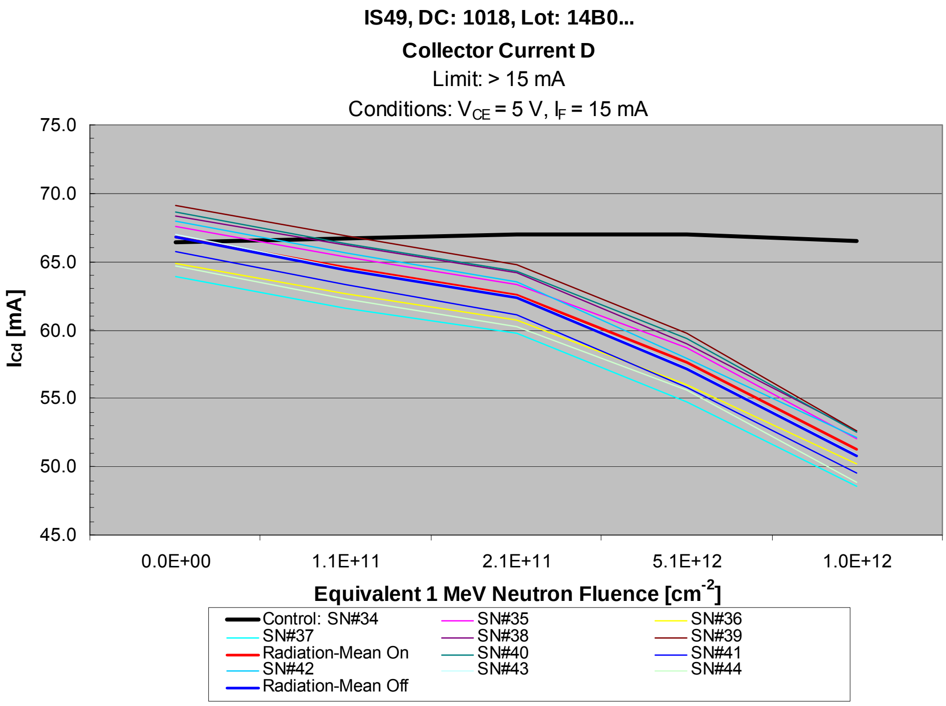
Collector Current D I_{Cd} [mA] **IS49**
Conditions: V_{CE} = 5 V, I_F = 15 mA Date Code: 1018
Limit: > 15 mA Lot:
Accuracy: -- LED: 14B08030- 11J3821D0
PD: 14B09050- 8460956050

ON-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#35	67.5880	65.3560	63.3100	58.7260	52.0540
SN#36	64.9110	62.6250	60.6820	56.0330	50.2410
SN#37	63.9430	61.6390	59.7500	54.7350	48.6110
SN#38	68.3290	66.1790	64.1480	58.9850	52.5740
SN#39	69.0920	66.9140	64.7750	59.7990	52.6540
Radiation-Mean On	**66.7726**	**64.5426**	**62.5330**	**57.6556**	**51.2268**
Standarddeviation	**2.2327**	**2.2952**	**2.2028**	**2.1604**	**1.7572**
Control: SN#34	66.4000	66.7230	66.9860	67.0120	66.4720

OFF-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	0.0E+00	1.1E+11	2.1E+11	5.1E+12	1.0E+12
SN#40	68.6810	66.3140	64.2480	59.3340	52.5610
SN#41	65.7160	63.3290	61.1540	55.8200	49.5220
SN#42	67.9470	65.6310	63.5270	57.9440	52.1300
SN#43	66.9750	64.4670	62.4790	57.2730	50.8500
SN#44	64.7170	62.2280	60.2590	55.5780	48.8320
Radiation-Mean Off	**66.8072**	**64.3938**	**62.3334**	**57.1898**	**50.7790**
Standarddeviation	**1.6123**	**1.6619**	**1.6436**	**1.5530**	**1.6106**
Control: SN#34	66.4000	66.7230	66.9860	67.0120	66.4720

Table 12: Collector Current D

Figure 11: I_{Cd}



3.9 Collector Current E

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

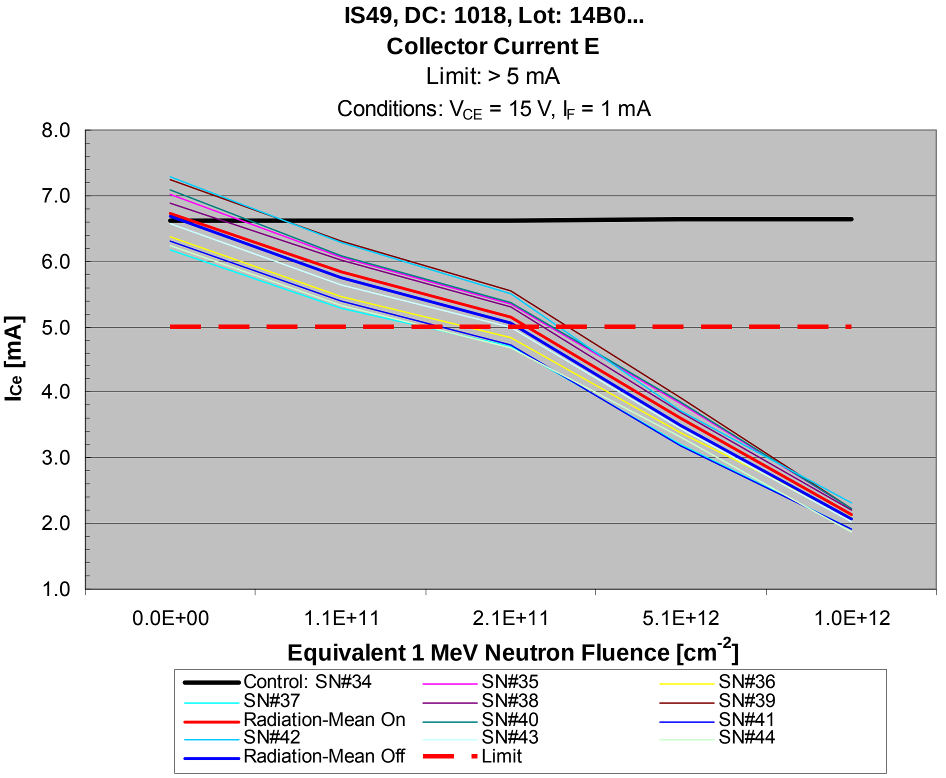
PD: 14B09050- 8460956050

ON-Mode	**Equivalent 1 MeV Neutron Fluence [cm^{-2}]**				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#35	7.0260	6.0680	5.3540	3.8260	2.2290
SN#36	6.3700	5.4570	4.8250	3.3860	2.0890
SN#37	6.1680	5.2860	4.6910	3.2080	1.9110
SN#38	6.8800	6.0090	5.3100	3.7000	2.2080
SN#39	7.2380	6.3130	5.5420	3.9210	2.2300
Radiation-Mean On	**6.7364**	**5.8266**	**5.1444**	**3.6082**	**2.1334**
Standarddeviation	**0.4509**	**0.4350**	**0.3664**	**0.3013**	**0.1374**
Control: SN#34	6.6280	6.6270	6.6280	6.6330	6.6310

OFF-Mode	**Equivalent 1 MeV Neutron Fluence [cm^{-2}]**				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#40	7.0810	6.0920	5.3750	3.8500	2.2370
SN#41	6.3000	5.4020	4.7160	3.1950	1.9180
SN#42	7.2840	6.2810	5.5000	3.7100	2.3050
SN#43	6.5740	5.6260	4.9830	3.4620	2.0360
SN#44	6.2300	5.3190	4.6890	3.3110	1.8730
Radiation-Mean Off	**6.6938**	**5.7440**	**5.0526**	**3.5056**	**2.0738**
Standarddeviation	**0.4698**	**0.4246**	**0.3723**	**0.2723**	**0.1911**
Control: SN#34	6.6280	6.6270	6.6280	6.6330	6.6310

Table 13: Collector Current E

Figure 12: I_{Ce}



3.10 Collector-Emitter 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

Accuracy: --

Lot:

LED: 14B08030- 11J3821D0

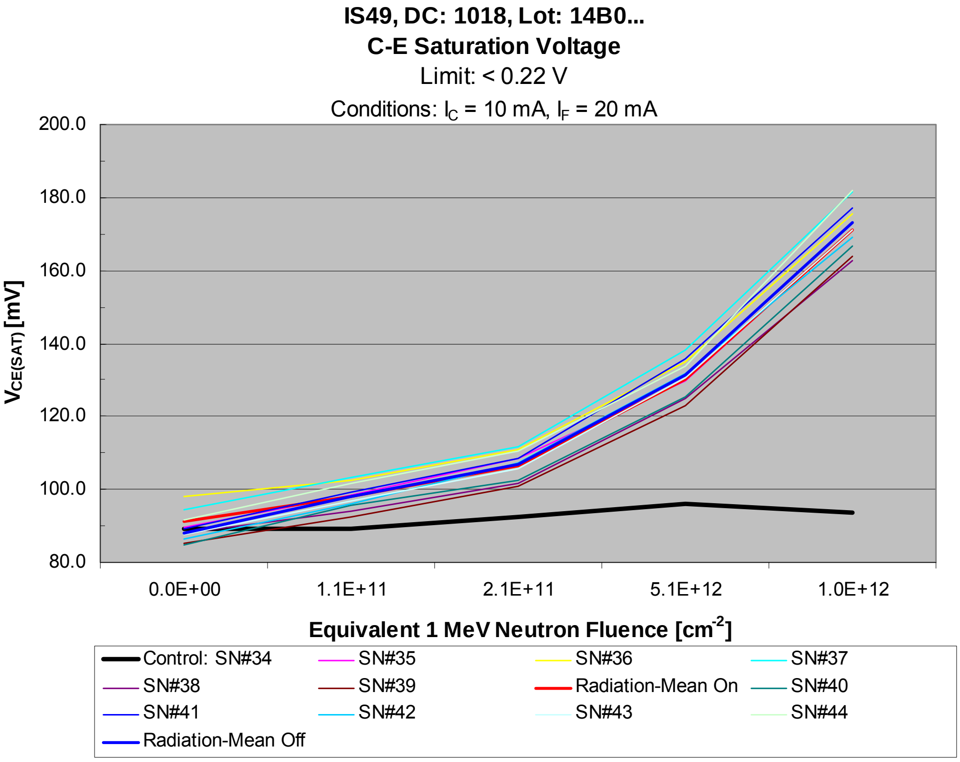
PD: 14B09050- 8460956050

ON-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#35	89.7580	98.3800	108.3180	129.8380	171.0720
SN#36	97.9280	102.3540	110.7640	135.1340	175.5880
SN#37	94.2820	103.2080	111.6240	138.0460	181.6280
SN#38	88.0040	94.1540	101.7420	125.0340	162.5820
SN#39	85.2220	92.5080	100.9140	122.9620	164.0800
Radiation-Mean On	**91.0388**	**98.1208**	**106.6724**	**130.2028**	**170.9900**
Standarddeviation	**5.0662**	**4.7725**	**5.0358**	**6.4248**	**7.9492**
Control: SN#34	89.2840	89.2560	92.4400	96.0320	93.5380

OFF-Mode	Equivalent 1 MeV Neutron Fluence [cm^{-2}]				
Counter	**0.0E+00**	**1.1E+11**	**2.1E+11**	**5.1E+12**	**1.0E+12**
SN#40	84.7180	95.6780	102.2960	125.1740	166.6960
SN#41	89.3740	99.1360	108.3980	135.7700	177.2340
SN#42	86.5800	96.0640	107.1920	131.7620	169.2220
SN#43	87.7020	97.0260	105.5060	130.4920	171.0720
SN#44	91.5180	101.5460	110.4480	133.9240	181.7440
Radiation-Mean Off	**87.9784**	**97.8900**	**106.7680**	**131.4244**	**173.1936**
Standarddeviation	**2.6047**	**2.4440**	**3.0810**	**4.0368**	**6.1629**
Control: SN#34	89.2840	89.2560	92.4400	96.0320	93.5380

Table 14: Collector-Emitter Saturation Voltage

Figure 13: $V_{CE(sat)}$



Appendix 1: RVT-TES-11/026/STO, Issue B

TESAT SPACECOM Project: Z	IRRADIATION TEST PLAN NO.: RVT-TES-11/026/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	Fraunhofer INT	Single: --- Multiple: X	No: X Yes:

Parts Identification	
Control Size: 1	S/N: #12
Irradiated Samples Size: 10	
ON-Mode Sample Size: 5	S/N: #13, 14, 15, 16, 17,
OFF-Mode Sample Size: 5	S/N: #18, 19, 20, 21, 22

Irradiation Steps

Irradiation with Neutrons 2 – 14 MeV

First step: irradiation up to a fluence of 1 10^11 neutrons/cm^2(equivalent to 1MeV neutrons)
Second step: irradiation up to a fluence of 2 10^11 neutrons/cm^2(equivalent to 1MeV neutrons)
Third step: irradiation up to a fluence of 5 10^11 neutrons/cm^2(equivalent to 1MeV neutrons)
Fourth step: irradiation up to a fluence of 1 10^12 neutrons/cm^2(equivalent to 1MeV neutrons)

Electrical Measurements

Parameter 2)	**Symbol**	**Condition 3)**	**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 **4)**	> 35 mA
Collector Current D	I_{Cd}	V_{CE} = 5 V, I_F = 15.0 mA **4)**	> 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) Parameters listed shall be tested before and after each radiation step and each annealing step.
3) Conditions as defined in Table 4-1 of test specification.
4) Pulse Condition as defined in Table 4-1 of test specification.

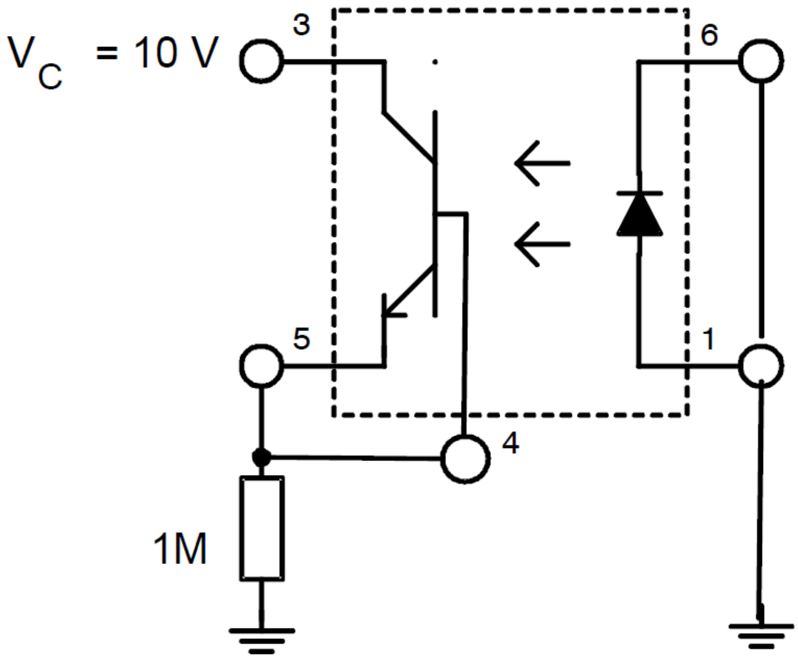
RVT-TES-11/026/STO Iss.B page 1

1. Annealing

- not applicable -

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.

RVT-TES-11/026/STO Iss.B page 2