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estec

European Space Research
and Technology Centre
Keplerlaan 1
2201 AZ Noordwijk
The Netherlands
T +31 (0)71 565 6565
F +31 (0)71 565 6040
www.esa.int

DOCUMENT

RA0585-E
Co60 TID Test Results on Part Type 66191 (Micropac)

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Prepared by	**Alessandra Costantino (TEC-QTC)**
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Details on available datasheets	06/10/2011	5	3.2
Indication of initial and intermediate CTR values	06/10/2011	24	6

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1 INTRODUCTION

The following report describes irradiation tests performed on the Micropac 66191 optocoupler to characterise radiation sensitivity variations observed in the two versions of the device used on ESA missions. The Micropac optocoupler 66191 is manufactured employing a 660 nm AlGaAs LED coupled to a photodiode and a 2N2222 transistor (Figure 1).

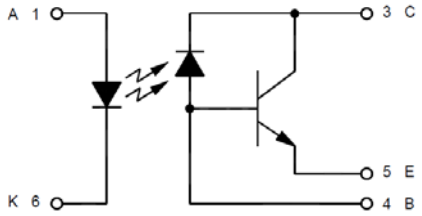


Figure 1: 66191 electrical layout

There are two version of the 66191 employed in ESA projects. The older version, 66191-303, contains a 2N2222 transistor from Microsemi. The newer optocoupler version, 66191-313, employs an in-house (Micropac) 2n2222 and replaces the Microsemi transistor. Micropac state that the in-house transistor was selected following TID radiation evaluation of 2N2222 transistors from different manufacturers. TID evaluation testing was carried out by Micropac at high dose rates. At the time of writing it is not known whether Micropac also performed Displacement Damage testing on the new version of the 66191-313.

The ESA TID tests of the 66191 were initiated due to an unexpected increased TID sensitivity observed following low dose rate (108rad(Si)/h) TID irradiation testing of the 66191-313 by Alter for an ESA projec. The irradiation tests were performed biased and unbiased.

The scope of the irradiation tests described here is to perform low dose rate testing on the two versions of the 66191 and to establish whether the 2N2222 is the source of the observed increased TID sensitivity mentioned above. Additionally, these tests are performed to verify findings by Alter. The tests were performed at various biasing conditions based on information received from ESA projects.

2 REFERENCES

REF1 ESA/SCC 22900 “Total Dose Steady-State Irradiation Test Method”, issue 3
REF2 ESSB-ST-Q-001, “Space product assurance - Radiation Hardness Assurance” Issue 1

3 TEST DESCRIPTION

3.1 Facility and Dosimetry

The ESTEC Co-60 facility comprises of a Nordion Gammabeam 150C irradiator containing a nominal 74.8 TBq (2000 Ci) Co-60 source at the last reload date in June 2007. 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).

3.2 Devices Under Test

A total of 20 devices were received from Micropac, ten (10) 66191-303 devices and ten (10) 66191-313 devices. The datasheet specification, reported in Annex A, refers to screened devices with reference 66191-300 (S-level screening). The 66191-300 specification is also applicable to part types 66191-303 and 66191-313. No specific datasheet is available for the 66191-303 and 66191-313.

Parts description:

Component Designation	**66191-303**
Manufacturer	Micropac
Family	Opto-electronics
Group	Optocoupler
Package	6 pin, hermetically sealed Leadless Ceramic Carrier
Lot date code	1004
Device serial numbers	180, 187, 188, 189, 190, 195, 199, 201, 205, 206

Component Designation	**66191-313**
Manufacturer	Micropac
Family	Opto-electronics
Group	Optocoupler
Package	6 pin, hermetically sealed Leadless Ceramic Carrier
Lot date code	1031
Device serial numbers	211, 217, 220, 221, 223, 224, 225, 228, 237, 238

3.3 Biasing conditions

For both device versions the following biasing conditions were applied during irradiation:

A) 3 samples in On mode. Vce = 0V (Vce sat), Ic = 1mA, Ib = 0A (disconnected), I LED=10mA;

B) 3 samples in Off mode. Vce = 12V, Ic = 0A, Ib = 0A (disconnected), I LED = 0A (grounded);

C) 4 samples biased with ILED=10mA, receiver pins grounded.

To ensure stability and functionality of the measurement system a Micropac 66223 optocoupler was used as reference device and was electrically tested before and after each optocoupler electrical measurement.

Par type	S/n's	Description
66191-303	180, 187, 188	Biased during ^{60}Co irradiation, biasing condition A
66191-303	189, 190, 195	Biased during ^{60}Co irradiation, biasing condition B
66191-303	199, 201, 205, 206	Biased during ^{60}Co irradiation, biasing condition C
66191-313	211, 217, 220	Biased during ^{60}Co irradiation, biasing condition A
66191-313	221, 223, 224	Biased during ^{60}Co irradiation, biasing condition B
66191-313	225, 228, 237, 238	Biased during ^{60}Co irradiation, biasing condition C
66223	1	Reference device (not irradiated) - Electrically tested before and after each optocoupler electrical measurement

Table 1 Device Under Test biasing conditions

3.4 Radiation Test Plan

Irradiation tests were performed in accordance to REF1. This section provides a summary of the Radiation Test Plan with reference "20105".

The actual radiation test steps are reported in Table 2.

Step	Total Dose krad(Si)
(Pre irradiation) 0	0
Irradiation step # 1	6675
Irradiation step # 2	14229
Irradiation step # 3	20910
Irradiation step # 4	44851
Irradiation step # 5	63515
Irradiation step # 6	80696
Irradiation step # 7	105221

Table 2: Actual irradiation steps

The dose rate chosen was 360 rad (Si)/h, a lower dose rate was not employed because of time limitations.

Pre and post-irradiation electrical measurements and intermediate electrical measurements (following each irradiation step) were carried out as described in Section 3.5

At the end of the final irradiation run, all devices were electrically measured and annealed for 24 hours at room temperature and subsequently underwent accelerated aging at 100°C (for 168 hrs in total), maintaining the same bias conditions applied during the TID test. Table 3 reports the annealing/accelerated ageing sequence detail.

Step	Temperature	Duration
Anneal	Room temperature	24 hours
Accelerated Ageing	100 °C	168 hours

Table 3: Annealing information

3.5 Measurement Setup

No in-situ measurements were performed during irradiation.
The electrical characterisation was performed after each irradiation, annealing and ageing step as follows:

1 OC Performances
   a. Current Transfer Ratio (CTR) @ Vce=1V If=0.1-40mA
   b. Saturation Voltage @ If=20mA Ic=10mA
2 Phototransistor performances
   a. Collector emitter dark current @Vce= 20V
   b. Collector emitter off (BR) @Vce= 40V
   c. Collector base off (BR) @Veb = 5V
   d. Emitter collector off (BR) @Vce= 40V
3 LED performances
   a. Current Voltage Characteristic @If=0.1÷40mA
   b. Reverse Current @V=-3

All above parameters were measured using the following equipment:
Parameter analyzer: Agilent 4156C (s/n JPIOJ00469)
Text Fixture Agilent: 16442A
All measurements were controlled by an automatic test program using Wavevue (Microvue), the acquired data were analyzed with Microsoft Excel.

All measurements have been archived but only CTR measurements have been presented in this report.

4 TEST RESULTS

The test results are shown in sections 4.1 to 4.5. Due to the limited number of samples available, the one sided tolerance limit statistical method has been applied to treat the irradiation test results in accordance to REF.2.
One device (Sample 190, 66191-303, biasing condition B) failed during irradiation after 14229 rad(Si) due to an electrical overstress. For this biasing group, with only two samples remaining, statistical analysis was not possible; for this reason the corresponding graphs report only the average of measured data without the 90% probability with 90% confidence limits.

4.1 CTR decrease with radiation

Measurements on all tested parts

CTR @If=10mA, Vce=1V

Part type	Biasing condition	s/n	Dose (rad(Si)) 0	6675	14229	20910	44851	63515	80696	105221	Last irradiation	Annealing hours @ RT 24	Ageing hours @ 100°C 168
66191-313	A	211	2.25	1.66	1.37	1.22	0.88	0.73	0.65	0.58	0.58	0.6	1.21
66191-313	A	217	2.05	1.46	1.2	1.06	0.75	0.62	0.55	0.49	0.49	0.5	1.08
66191-313	A	220	1.71	1.26	1.04	0.92	0.68	0.58	0.53	0.47	0.47	0.49	0.91
66191-313	B	221	2.23	1.61	1.31	1.13	0.68	0.48	0.38	0.3	0.3	0.31	1.06
66191-313	B	223	2.38	1.72	1.41	1.23	0.74	0.53	0.43	0.34	0.34	0.34	1.16
66191-313	B	224	2.56	1.86	1.52	1.34	0.87	0.66	0.54	0.43	0.43	0.44	1.28
66191-313	C	225	1.95	1.41	1.14	0.99	0.58	0.41	0.33	0.27	0.27	0.28	1
66191-313	C	228	2.09	1.42	1.09	0.92	0.52	0.38	0.31	0.26	0.26	0.27	0.98
66191-313	C	237	1.96	1.39	1.14	0.99	0.6	0.43	0.35	0.28	0.28	0.28	0.98
66191-313	C	238	2.04	1.37	1.08	0.91	0.53	0.38	0.32	0.27	0.27	0.27	0.98
66191-303	A	180	4.5	3.74	3.36	3.18	2.78	2.58	2.44	2.28	2.28	2.29	2.79
66191-303	A	187	4.72	3.88	3.5	3.35	3.01	2.83	2.71	2.55	2.55	2.55	2.98
66191-303	A	188	3.75	3.08	2.75	2.6	2.27	2.1	1.99	1.85	1.85	1.86	2.29
66191-303	B	189	4.28	3.53	3.22	3.1	2.82	2.59	2.5	2.38	2.38	2.39	2.73
66191-303	B	190	4.03	3.29	2.97								
66191-303	B	195	4.07	3.27	2.928	2.77	2.4	2.21	2.08	1.91	1.91	1.91	2.522
66191-303	C	199	4.42	3.64	3.27	3.1	2.65	2.43	2.27	2.06	2.06	2.07	0
66191-303	C	201	3.44	2.81	2.5	2.35	2.02	1.87	1.76	1.64	1.64	1.64	2.15
66191-303	C	205	3	2.42	2.16	2.04	1.74	1.59	1.49	1.37	1.37	1.38	1.84
66191-303	C	206	4.18	3.46	3.13	2.94	2.56	2.37	2.24	2.07	2.07	2.07	2.68

Table 4: CTR (@Vce=1V, If=10mA) measured at every dose step for each tested sample.

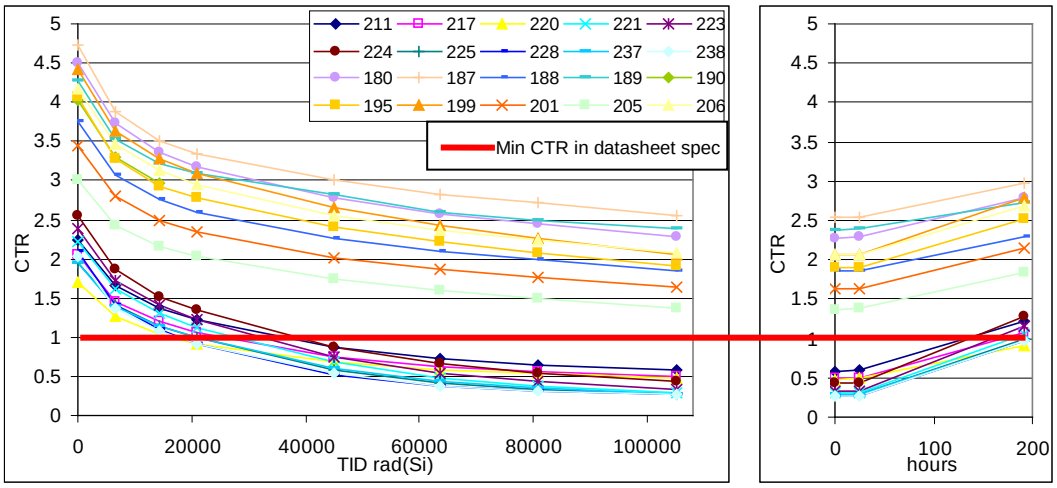


Figure 2 : CTR degradation of each tested part due to TID irradiation.

4.2 Normalised CTR decrease with radiation

Measurements on all tested parts

Normalized CTR @If=10mA, Vce=1V

Part type	Biasing condition	s/n	Dose (rad(Si)) 0	6675	14229	20910	44851	63515	80696	105221	Last TID step 0	Annealing hours @ RT 24	Ageing hours @ 100°C 168
66191-313	A	211	1.00	0.74	0.61	0.54	0.39	0.32	0.29	0.26	0.26	0.27	0.54
66191-313	A	217	1.00	0.71	0.59	0.52	0.37	0.30	0.27	0.24	0.24	0.24	0.53
66191-313	A	220	1.00	0.74	0.61	0.54	0.40	0.34	0.31	0.27	0.27	0.29	0.53
66191-313	B	221	1.00	0.72	0.59	0.51	0.30	0.22	0.17	0.13	0.13	0.14	0.48
66191-313	B	223	1.00	0.72	0.59	0.52	0.31	0.22	0.18	0.14	0.14	0.14	0.49
66191-313	B	224	1.00	0.73	0.59	0.52	0.34	0.26	0.21	0.17	0.17	0.17	0.50
66191-313	C	225	1.00	0.72	0.58	0.51	0.30	0.21	0.17	0.14	0.14	0.14	0.51
66191-313	C	228	1.00	0.68	0.52	0.44	0.25	0.18	0.15	0.12	0.12	0.13	0.47
66191-313	C	237	1.00	0.71	0.58	0.51	0.31	0.22	0.18	0.14	0.14	0.14	0.50
66191-313	C	238	1.00	0.67	0.53	0.45	0.26	0.19	0.16	0.13	0.13	0.13	0.48
66191-303	A	180	1.00	0.83	0.75	0.71	0.62	0.57	0.54	0.51	0.51	0.51	0.62
66191-303	A	187	1.00	0.82	0.74	0.71	0.64	0.60	0.57	0.54	0.54	0.54	0.63
66191-303	A	188	1.00	0.82	0.73	0.69	0.61	0.56	0.53	0.49	0.49	0.50	0.61
66191-303	B	189	1.00	0.82	0.75	0.72	0.66	0.61	0.58	0.56	0.56	0.56	0.64
66191-303	B	190	1.00	0.82	0.74								
66191-303	B	195	1.00	0.80	0.72	0.68	0.59	0.54	0.51	0.47	0.47	0.47	0.62
66191-303	C	199	1.00	0.82	0.74	0.70	0.60	0.55	0.51	0.47	0.47	0.47	0.63
66191-303	C	201	1.00	0.82	0.73	0.68	0.59	0.54	0.51	0.48	0.48	0.48	0.63
66191-303	C	205	1.00	0.81	0.72	0.68	0.58	0.53	0.50	0.46	0.46	0.46	0.61
66191-303	C	206	1.00	0.83	0.75	0.70	0.61	0.57	0.54	0.50	0.50	0.50	0.64

Table 5 CTR (Vce=1V, If=10mA) normalised to the pre-irradiation measurement. The data are reported for every dose step, for each tested sample

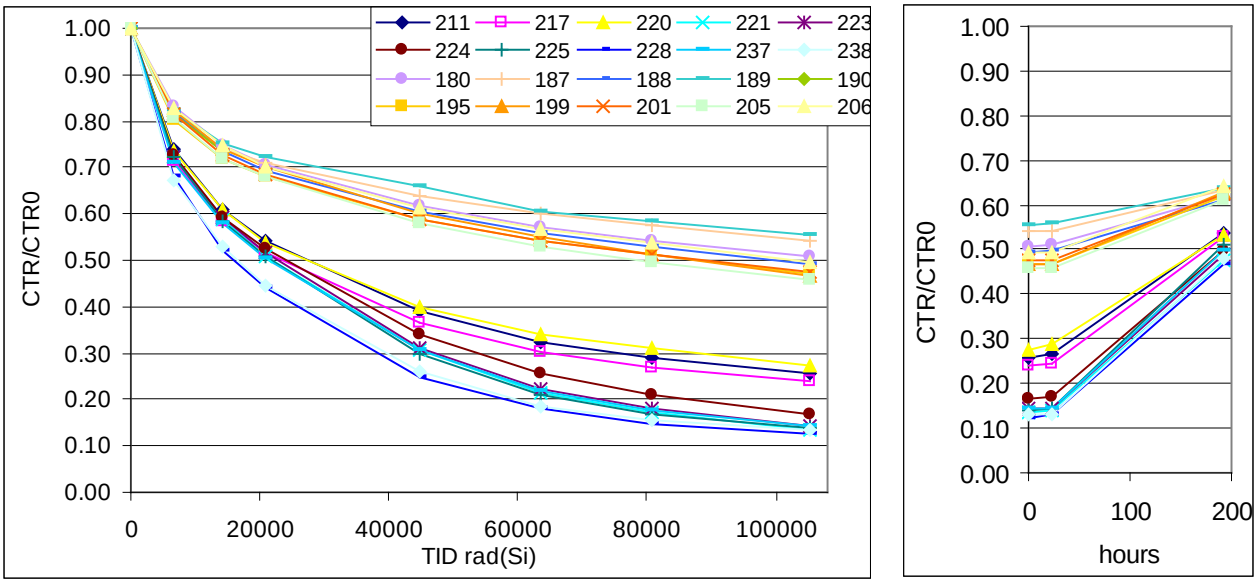


Figure 3: CTR after irradiation normalised to initial CTR value for each tested part.

4.3 Average CTR degradation for each biasing group

Part type	Biasing Condition	Dose (rad(Si)) 0	6675	14229	20910	44851	63515	80696	105221	Last irradiation 0	20.7 24	27.8 192
66191-313	A	2.00	1.46	1.20	1.07	0.77	0.64	0.58	0.51	0.51	0.53	1.07
66191-313	B	2.39	1.73	1.41	1.23	0.76	0.56	0.45	0.36	0.36	0.36	1.17
66191-313	C	2.01	1.40	1.11	0.95	0.56	0.40	0.33	0.27	0.27	0.28	0.99
66191-303	A	4.32	3.57	3.20	3.04	2.69	2.50	2.38	2.23	2.23	2.23	2.69
66191-303	B	4.13	3.36	3.04	2.94	2.61	2.40	2.29	2.15	2.15	2.15	2.63
66191-303	C	3.76	3.08	2.77	2.61	2.24	2.07	1.94	1.79	1.79	1.79	2.36

Table 6 Average CTR (@Vce=1V, If=10mA) within the biasing group, at every dose step.

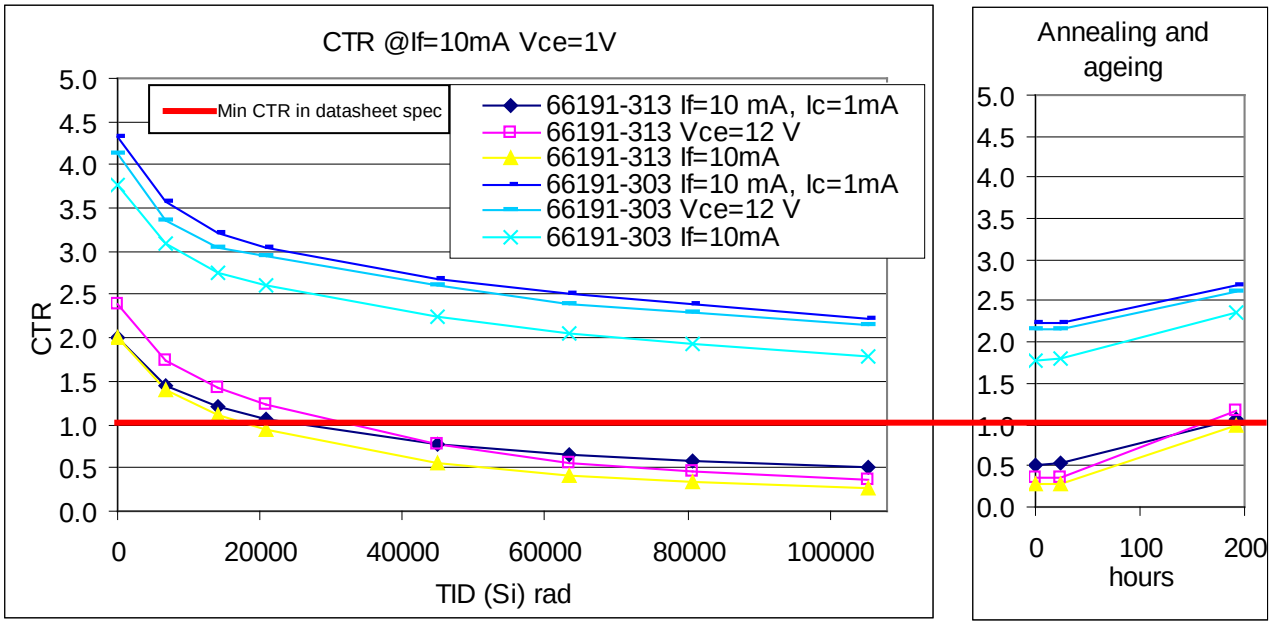


Figure 4: CTR degradation for each biasing condition applied during TID irradiation (average on all tested samples of the same biasing group). Figure 5 compares the trend of each biasing group and the limits of 90% confidence.

Average CTR degradation of the samples belonging to the same biasing group

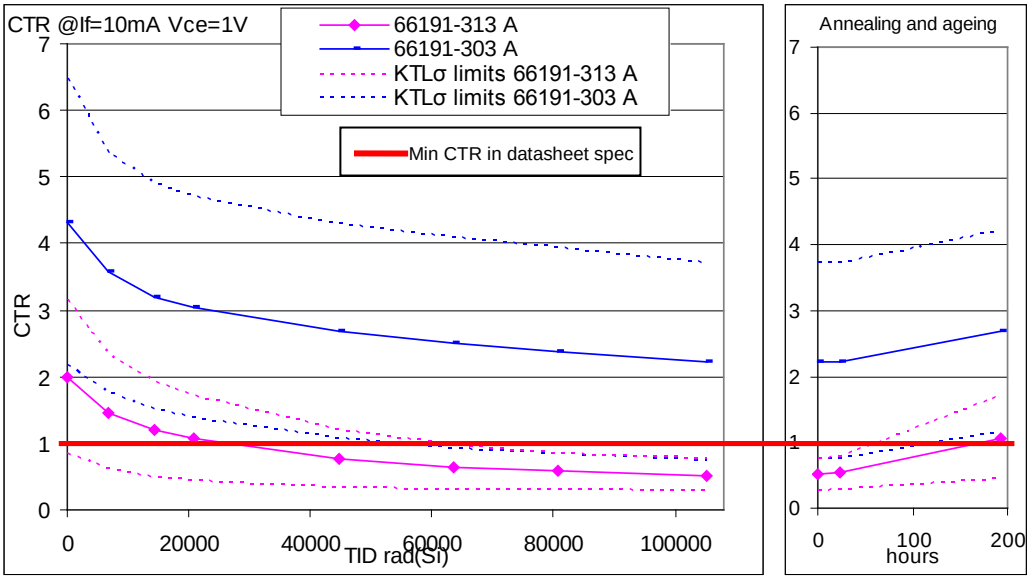


Figure 5.I– Biasing group A

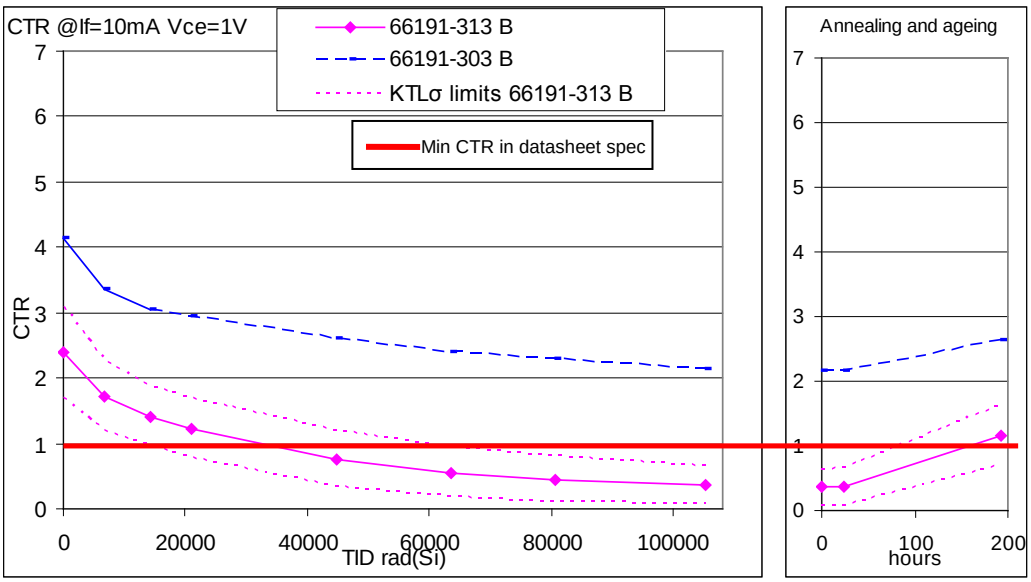


Figure 5.II– Biasing group B

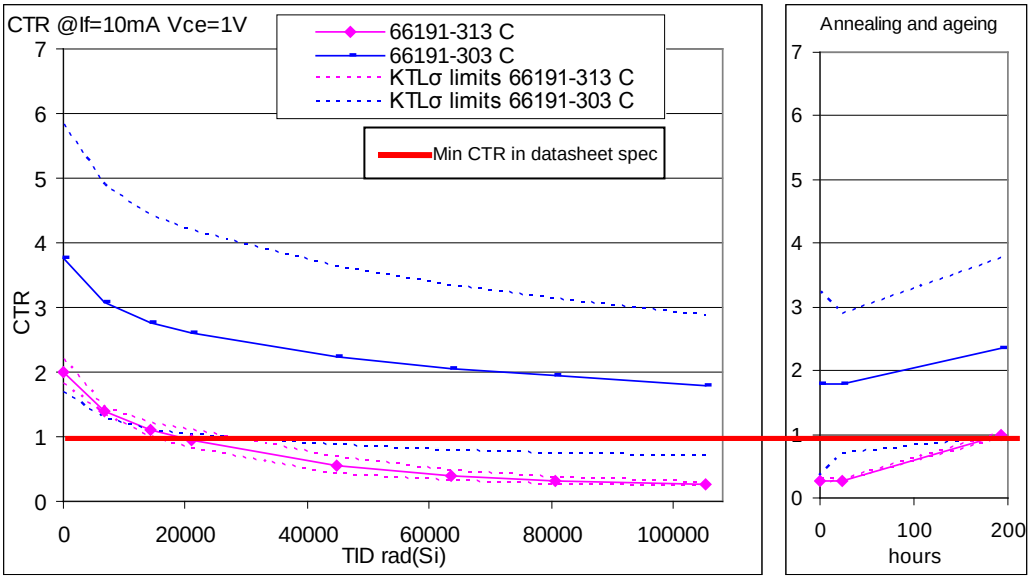


Figure 5.III– Biasing group C

Figure 5 Comparison of CTR decrease for each biasing group. The plotted points are the average of CTR measured at each irradiation step on the samples belonging to the same biasing group. There is 90% probability with 90% confidence that the electrical parameters will be within the limits indicated by the dashed lines (one sided tolerance limit statistical treatment of data).

4.4 Normalised average CTR decrease for each biasing group

Part type	Biasing Condition	Dose (rad(Si))								Last irradiation		
		0	6675	14229	20910	44851	63515	80696	105221	0	24	168
66191-313	A	2.00	1.46	1.20	1.07	0.77	0.64	0.58	0.51	0.51	0.53	1.07
66191-313	B	2.39	1.73	1.41	1.23	0.76	0.56	0.45	0.36	0.36	0.36	1.17
66191-313	C	2.01	1.40	1.11	0.95	0.56	0.40	0.33	0.27	0.27	0.28	0.99
66191-303	A	4.32	3.57	3.20	3.04	2.69	2.50	2.38	2.23	2.23	2.23	2.69
66191-303	B	4.13	3.36	3.04	2.94	2.61	2.40	2.29	2.15	2.15	2.15	2.63
66191-303	C	3.76	3.08	2.77	2.61	2.24	2.07	1.94	1.79	1.79	1.79	2.36

Table 7 CTR (@Vce=1V, If=10mA) normalised to the pre-irradiation measurement, average within the biasing group, at every dose step.

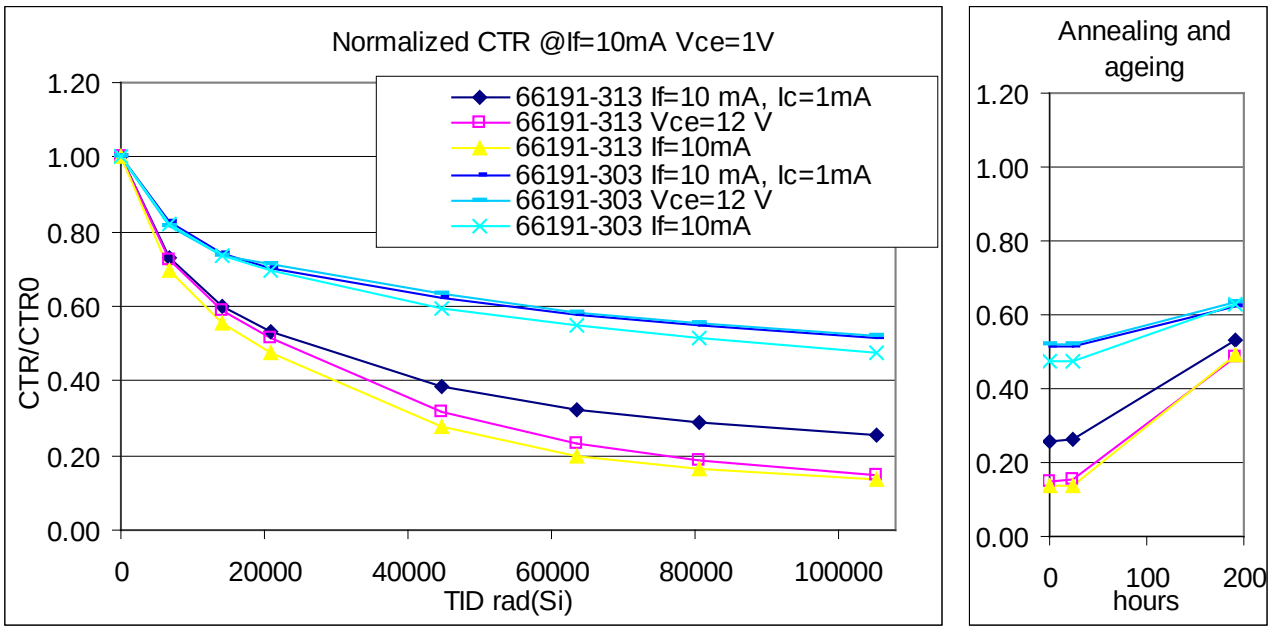


Figure 6: CTR after irradiation normalised to initial CTR value.
The graph reports the trend for all the three biasing condition applied during TID. The plotted points are the average on the samples belonging to the same biasing group. Figure 7 compares the trend of each biasing group and the limits of 90% confidence.

Average of normalised CTR decrease of the samples belonging to the same biasing group

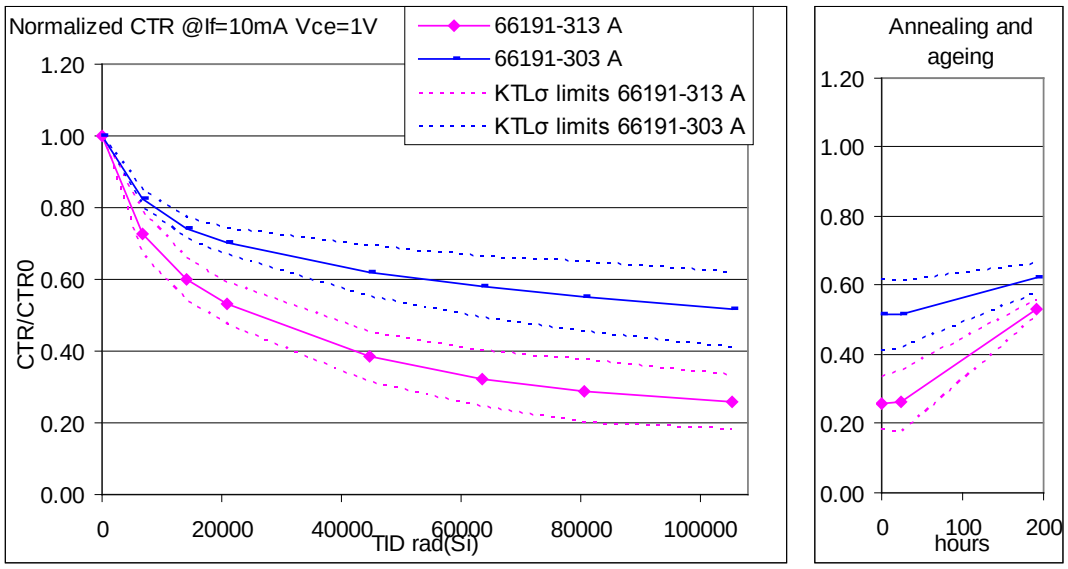


Figure 7. I – Biasing group A

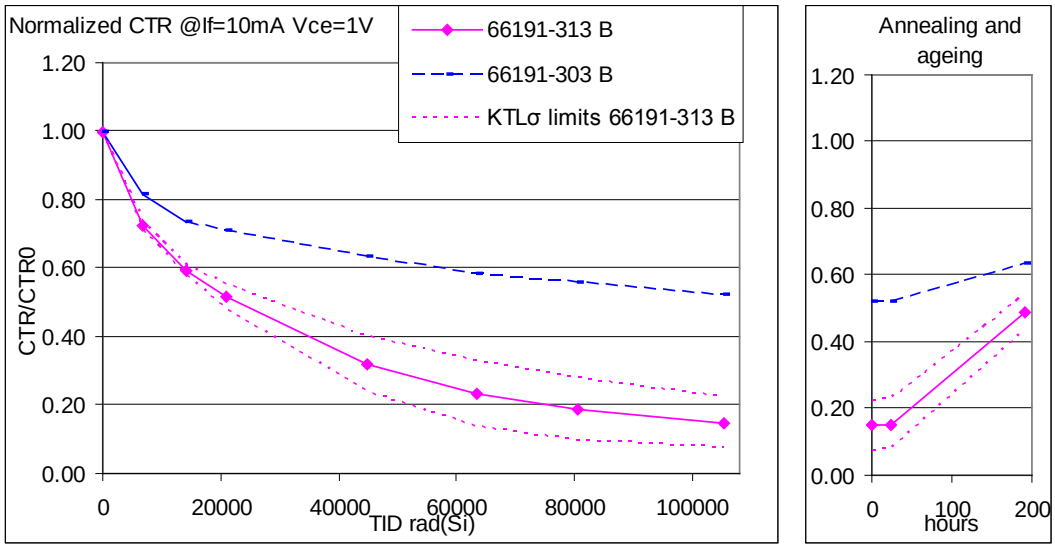


Figure 7. II Biasing group B

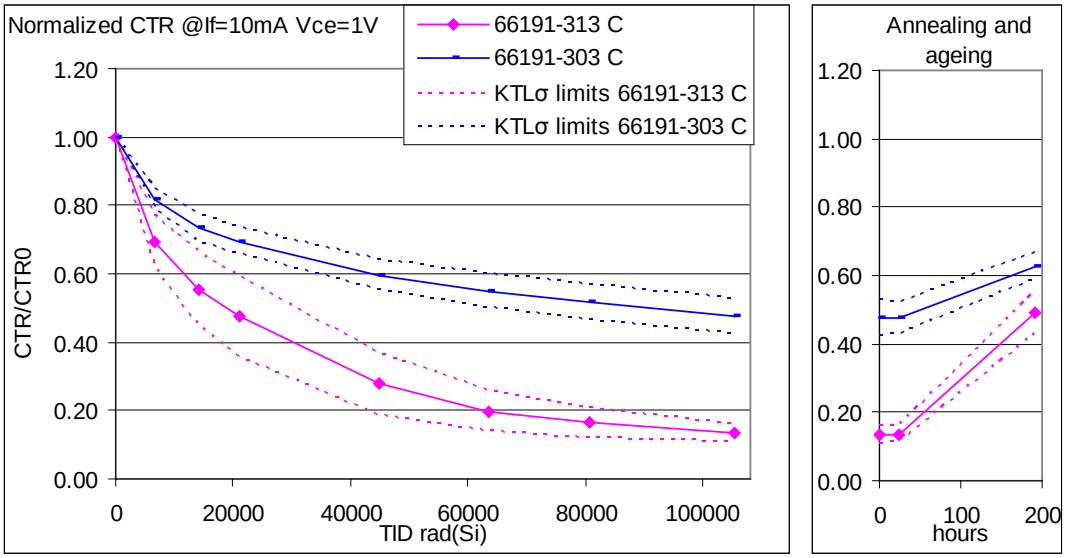


Figure 7. III Biasing group C

Figure 7: Comparison of trend of each biasing group. Plots report the average of normalised CTR on the samples belonging to the same biasing group. There is 90% probability with 90% confidence that the electrical parameters will be within the limits indicated by the dashed lines (one sided tolerance limit statistical treatment of data).

4.5 CTR characteristic at each step

Biasing A

y			dose									
PartType	biasing	If	0	6675	14229	20910	44851	63515	80696	105221	annealing 24h tamb	annealing 100C 168h
66191-303	A	0.1	0.307	0.218	0.181	0.162	0.112	0.088	0.072	0.056	0.058	0.116
		0.1259	0.400	0.290	0.243	0.218	0.156	0.124	0.103	0.081	0.083	0.160
		0.1585	0.516	0.380	0.321	0.290	0.212	0.171	0.144	0.115	0.118	0.217
		0.1996	0.655	0.489	0.416	0.378	0.281	0.231	0.197	0.159	0.163	0.286
		0.2514	0.820	0.618	0.529	0.483	0.366	0.304	0.263	0.215	0.220	0.370
		0.3165	1.009	0.766	0.660	0.605	0.465	0.392	0.342	0.284	0.290	0.468
		0.3985	1.221	0.934	0.808	0.743	0.580	0.494	0.436	0.367	0.374	0.579
		0.5018	1.451	1.117	0.971	0.895	0.707	0.608	0.542	0.461	0.469	0.703
		0.6319	1.695	1.314	1.146	1.058	0.846	0.734	0.659	0.568	0.576	0.838
		0.7956	1.951	1.520	1.330	1.231	0.995	0.871	0.788	0.686	0.694	0.982
		1.002	2.212	1.732	1.521	1.409	1.150	1.014	0.923	0.811	0.820	1.133
		1.261	2.472	1.946	1.714	1.594	1.312	1.165	1.068	0.946	0.956	1.291
		1.588	2.732	2.160	1.908	1.780	1.478	1.321	1.217	1.087	1.096	1.453
		2	2.985	2.370	2.100	1.963	1.645	1.479	1.369	1.232	1.241	1.617
		2.518	3.229	2.575	2.288	2.144	1.811	1.638	1.523	1.379	1.388	1.782
		3.171	3.459	2.771	2.468	2.318	1.974	1.795	1.677	1.527	1.536	1.945
		3.993	3.672	2.957	2.639	2.485	2.133	1.949	1.828	1.675	1.683	2.106
		5.027	3.866	3.130	2.800	2.642	2.286	2.099	1.976	1.820	1.828	2.263
		6.33	4.026	3.288	2.948	2.791	2.429	2.241	2.117	1.960	1.967	2.411
		7.971	4.153	3.422	3.079	2.922	2.560	2.374	2.251	2.093	2.099	2.550
		10.04	4.309	3.549	3.193	3.031	2.676	2.493	2.372	2.217	2.222	2.675
		12.64	4.393	3.645	3.285	3.126	2.776	2.594	2.479	2.327	2.332	2.789
		15.91	4.430	3.707	3.351	3.197	2.854	2.671	2.568	2.422	2.427	2.878
		20.04	4.177	3.701	3.362	3.233	2.896	2.685	2.632	2.493	2.497	2.929
66191-313	A	0.1	0.187	0.107	0.065	0.044	0.013	0.008	0.006	0.004	0.005	0.052
		0.1259	0.236	0.139	0.087	0.060	0.019	0.011	0.009	0.006	0.007	0.071
		0.1585	0.295	0.177	0.114	0.081	0.028	0.017	0.012	0.009	0.010	0.095
		0.1996	0.362	0.222	0.147	0.108	0.039	0.024	0.018	0.013	0.015	0.123
		0.2514	0.437	0.274	0.186	0.139	0.054	0.033	0.025	0.019	0.021	0.157
		0.3165	0.521	0.331	0.231	0.175	0.073	0.046	0.035	0.026	0.029	0.196
		0.3985	0.611	0.394	0.280	0.217	0.096	0.062	0.047	0.036	0.040	0.240
		0.5018	0.708	0.462	0.335	0.264	0.123	0.082	0.063	0.049	0.053	0.287
		0.6319	0.808	0.534	0.393	0.315	0.155	0.105	0.082	0.064	0.070	0.338
		0.7956	0.912	0.608	0.455	0.369	0.190	0.132	0.105	0.083	0.090	0.391
		1.002	1.018	0.685	0.519	0.426	0.230	0.163	0.131	0.105	0.114	0.446
		1.261	1.125	0.763	0.585	0.486	0.273	0.198	0.161	0.131	0.141	0.504
		1.588	1.232	0.842	0.652	0.547	0.319	0.236	0.195	0.160	0.172	0.563
		2	1.339	0.921	0.721	0.610	0.368	0.278	0.232	0.193	0.206	0.623
		2.518	1.443	1.000	0.790	0.674	0.420	0.323	0.273	0.229	0.243	0.684
		3.171	1.545	1.078	0.859	0.739	0.474	0.371	0.317	0.269	0.284	0.745
		3.993	1.645	1.156	0.929	0.805	0.530	0.421	0.364	0.312	0.328	0.808
		5.027	1.741	1.232	0.998	0.870	0.588	0.474	0.413	0.358	0.375	0.871
		6.33	1.832	1.308	1.066	0.936	0.647	0.529	0.465	0.407	0.424	0.935
		7.971	1.919	1.381	1.134	1.001	0.707	0.585	0.519	0.458	0.476	0.999
		10.04	1.997	1.453	1.199	1.066	0.767	0.643	0.575	0.511	0.529	1.062
		12.64	2.050	1.520	1.262	1.128	0.828	0.701	0.631	0.565	0.583	1.126
		15.91	2.039	1.572	1.319	1.188	0.887	0.758	0.687	0.619	0.637	1.186
		20.04	1.958	1.576	1.344	1.236	0.941	0.813	0.741	0.671	0.689	1.235

Table 8 Average CTR characteristic (If=1-20mA, Vce=1V) calculated on the samples of biasing group "A" for each irradiation step of both references.

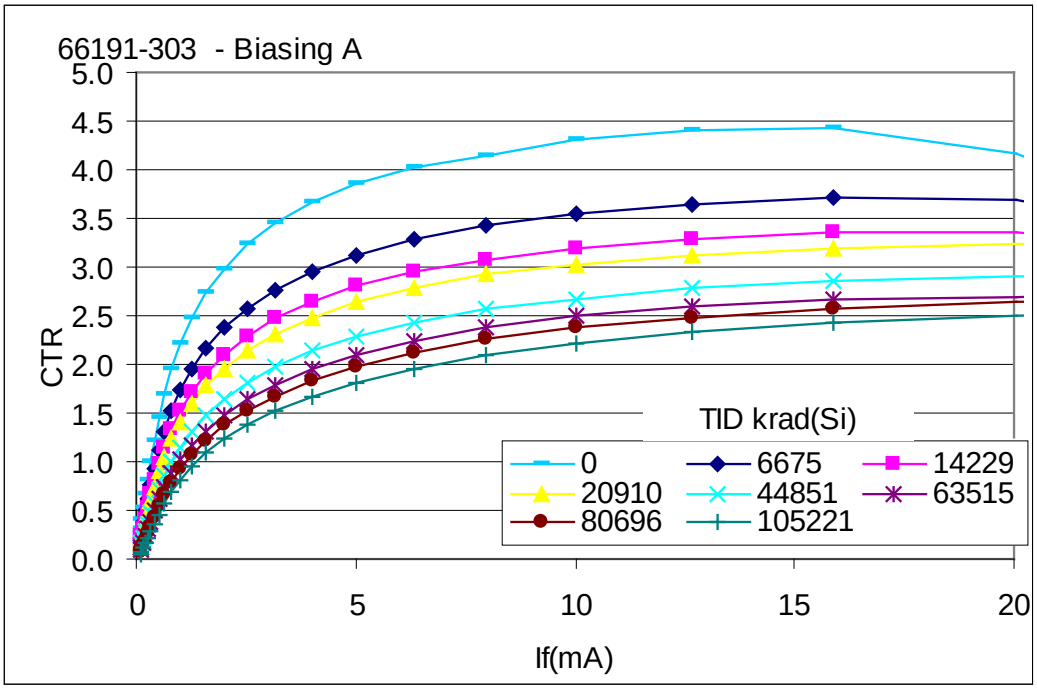


Figure 8: 66191-303 CTR characteristic degradation with TID irradiation (average on samples tested with biasing condition A).

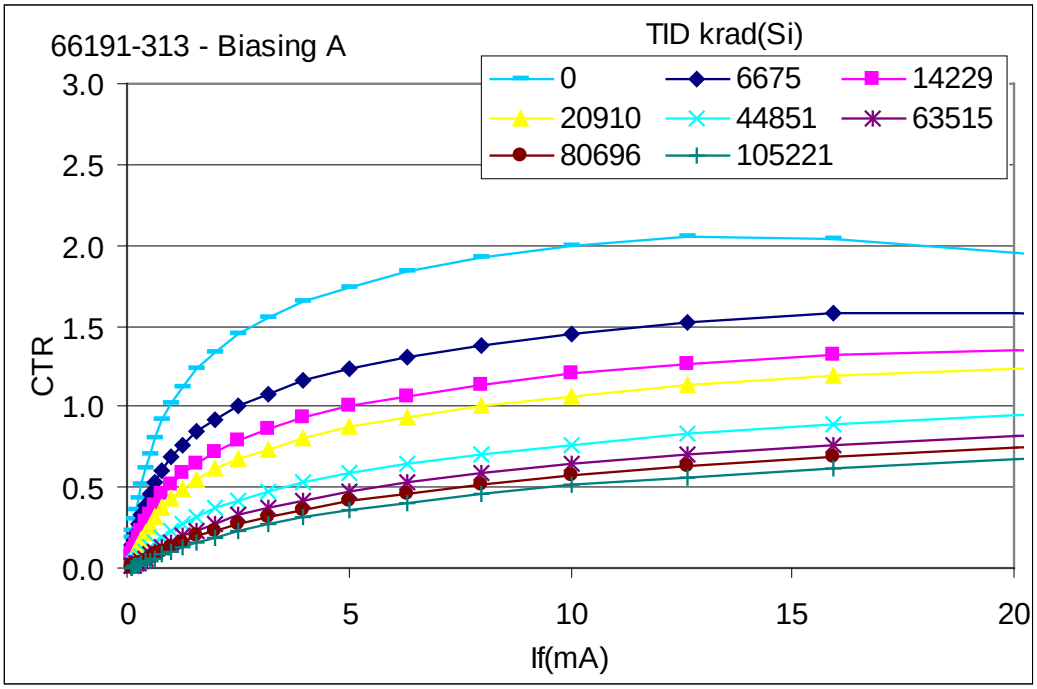


Figure 9: 66191-313 CTR characteristic degradation with TID irradiation (average on samples tested with biasing condition A).

Biasing B

PartType	biasing	If	0	6675	14229	20910	44851	63515	80696	105221	annealing 24h tamb	annealing 100C 168h
66191-303	B	0.1	0.366	0.224	0.168	0.153	0.074	0.054	0.047	0.039	0.039	0.089
		0.1259	0.471	0.299	0.229	0.211	0.108	0.080	0.070	0.058	0.059	0.127
		0.1585	0.599	0.392	0.306	0.284	0.155	0.116	0.102	0.084	0.086	0.177
		0.1996	0.749	0.505	0.401	0.373	0.216	0.163	0.144	0.120	0.122	0.241
		0.2514	0.920	0.637	0.514	0.481	0.293	0.225	0.199	0.167	0.170	0.320
		0.3165	1.112	0.787	0.643	0.604	0.386	0.300	0.268	0.226	0.229	0.415
		0.3985	1.322	0.954	0.790	0.745	0.496	0.392	0.350	0.299	0.302	0.526
		0.5018	1.545	1.134	0.949	0.897	0.621	0.497	0.447	0.384	0.388	0.651
		0.6319	1.778	1.324	1.120	1.061	0.759	0.617	0.557	0.482	0.487	0.789
		0.7956	2.017	1.520	1.298	1.233	0.909	0.749	0.680	0.593	0.598	0.938
		1.002	2.258	1.720	1.482	1.408	1.066	0.890	0.812	0.713	0.719	1.094
		1.261	2.495	1.918	1.665	1.588	1.232	1.041	0.954	0.845	0.851	1.259
		1.588	2.729	2.115	1.848	1.766	1.400	1.198	1.103	0.984	0.991	1.425
		2	2.954	2.306	2.028	1.941	1.569	1.358	1.257	1.129	1.136	1.593
		2.518	3.169	2.489	2.202	2.110	1.737	1.520	1.413	1.278	1.285	1.760
		3.171	3.370	2.663	2.367	2.272	1.902	1.680	1.570	1.429	1.436	1.923
		3.993	3.557	2.827	2.524	2.426	2.060	1.837	1.725	1.580	1.587	2.081
		5.027	3.725	2.979	2.670	2.571	2.212	1.989	1.876	1.729	1.737	2.231
		6.33	3.865	3.114	2.804	2.702	2.353	2.133	2.021	1.872	1.881	2.371
		7.971	3.979	3.226	2.922	2.818	2.484	2.268	2.157	2.009	2.018	2.500
		10.04	4.108	3.347	3.025	2.923	2.598	2.390	2.282	2.137	2.146	2.612
		12.64	4.179	3.434	3.108	3.009	2.696	2.497	2.393	2.253	2.261	2.708
		15.91	4.211	3.497	3.166	3.076	2.775	2.586	2.488	2.352	2.361	2.787
		20.04	4.155	3.522	3.195	3.114	2.827	2.649	2.558	2.428	2.437	2.812
66191-313	B	0.1	0.252	0.130	0.067	0.038	0.008	0.004	0.003	0.003	0.003	0.039
		0.1259	0.317	0.168	0.091	0.054	0.011	0.006	0.005	0.004	0.004	0.054
		0.1585	0.392	0.214	0.121	0.074	0.016	0.008	0.006	0.005	0.005	0.074
		0.1996	0.478	0.267	0.157	0.100	0.022	0.011	0.008	0.006	0.007	0.098
		0.2514	0.574	0.328	0.200	0.131	0.031	0.016	0.011	0.008	0.009	0.127
		0.3165	0.678	0.395	0.249	0.169	0.043	0.021	0.015	0.011	0.011	0.162
		0.3985	0.791	0.469	0.305	0.213	0.058	0.029	0.020	0.014	0.015	0.202
		0.5018	0.909	0.548	0.366	0.263	0.077	0.039	0.027	0.019	0.020	0.248
		0.6319	1.031	0.632	0.433	0.318	0.100	0.052	0.035	0.025	0.026	0.300
		0.7956	1.156	0.719	0.503	0.379	0.128	0.068	0.046	0.032	0.034	0.356
		1.002	1.283	0.810	0.578	0.443	0.160	0.087	0.060	0.042	0.044	0.416
		1.261	1.409	0.901	0.655	0.513	0.198	0.110	0.077	0.054	0.056	0.481
		1.588	1.534	0.994	0.735	0.585	0.241	0.138	0.098	0.069	0.072	0.549
		2	1.656	1.087	0.817	0.661	0.290	0.171	0.123	0.087	0.091	0.620
		2.518	1.776	1.180	0.900	0.738	0.343	0.209	0.153	0.110	0.114	0.692
		3.171	1.892	1.273	0.984	0.818	0.402	0.252	0.187	0.137	0.142	0.767
		3.993	2.003	1.365	1.069	0.899	0.466	0.301	0.227	0.168	0.175	0.844
		5.027	2.109	1.457	1.154	0.981	0.534	0.356	0.273	0.206	0.213	0.922
		6.33	2.210	1.547	1.239	1.064	0.606	0.417	0.326	0.249	0.257	1.001
		7.971	2.303	1.636	1.323	1.147	0.683	0.483	0.384	0.298	0.307	1.080
		10.04	2.381	1.721	1.405	1.230	0.762	0.555	0.448	0.354	0.364	1.159
		12.64	2.400	1.799	1.486	1.311	0.843	0.630	0.518	0.415	0.426	1.237
		15.91	2.327	1.829	1.557	1.389	0.925	0.709	0.593	0.482	0.494	1.310
		20.04	2.194	1.785	1.579	1.440	1.003	0.788	0.669	0.552	0.564	1.358

Table 9 Average CTR characteristic (If=1-20mA, Vce=1V) calculated calculated on the samples of biasing group "B" for each irradiation step of both references.

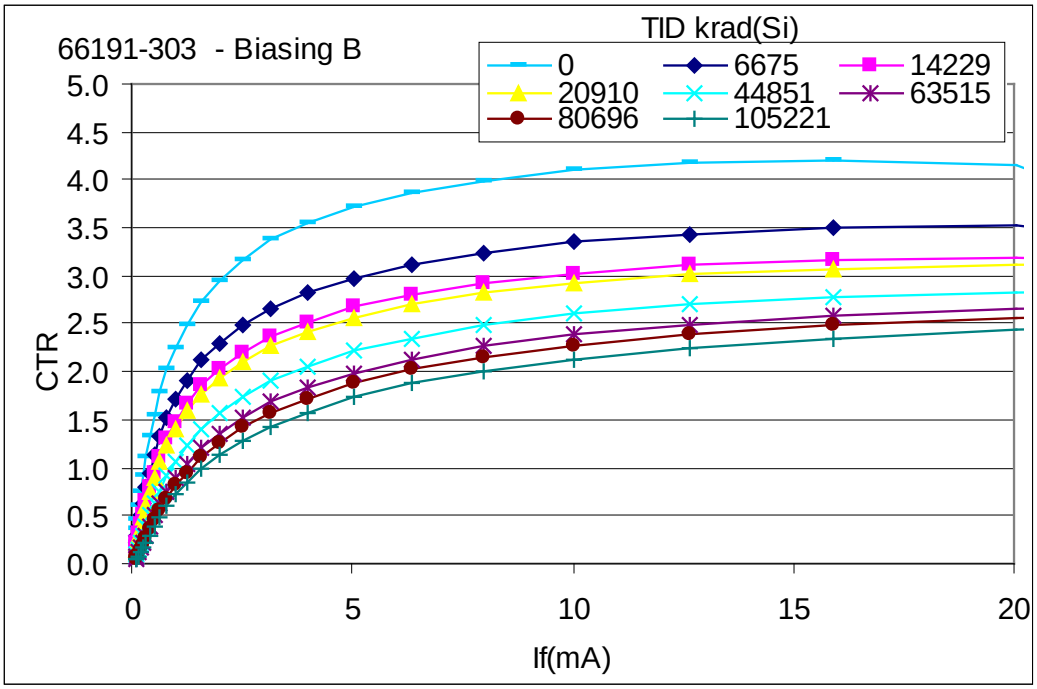


Figure 10: 66191-303 CTR characteristic degradation with TID irradiation (average on samples tested with biasing condition B).

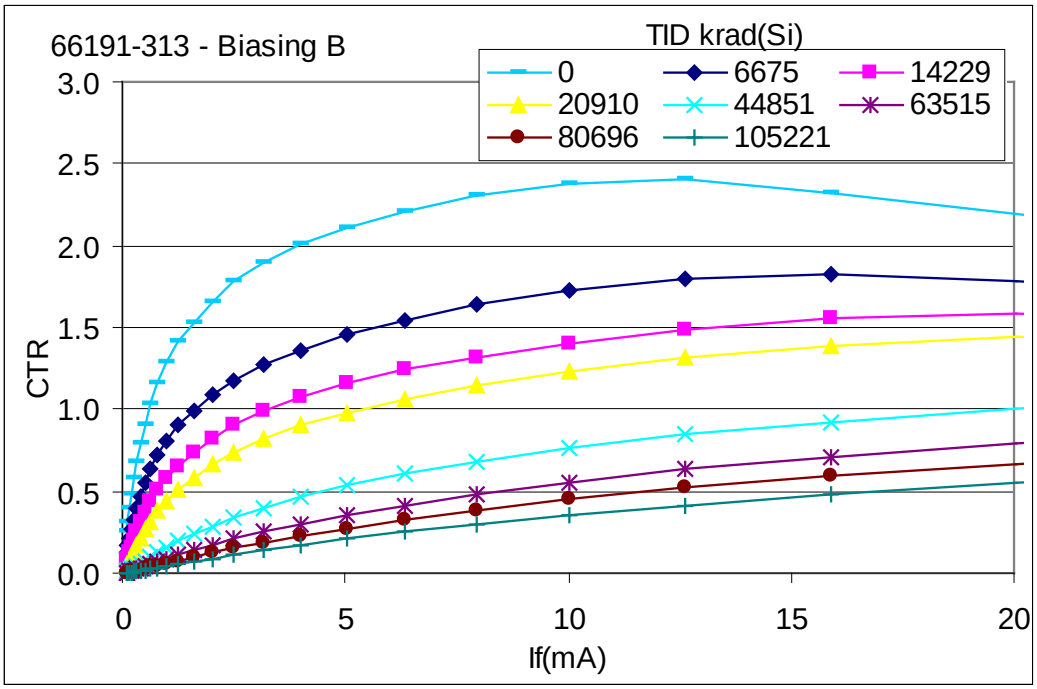


Figure 11: 66191-313 CTR characteristic degradation with TID irradiation (average on samples tested with biasing condition B).

Biasing C

y			dose									
PartType	biasing	x	0	6675	14229	20910	44851	63515	80696	105221	annealing 24h tamb	annealing 100C 168h
66191-303	C	0.1	0.328	0.203	0.145	0.114	0.055	0.037	0.029	0.021	0.021	0.072
		0.1259	0.424	0.273	0.200	0.160	0.082	0.056	0.044	0.032	0.032	0.104
		0.1585	0.541	0.360	0.270	0.220	0.118	0.083	0.065	0.048	0.049	0.147
		0.1996	0.680	0.465	0.357	0.295	0.167	0.120	0.095	0.071	0.072	0.203
		0.2514	0.839	0.588	0.460	0.387	0.228	0.167	0.135	0.102	0.103	0.273
		0.3165	1.017	0.728	0.579	0.494	0.303	0.227	0.186	0.143	0.144	0.358
		0.3985	1.212	0.884	0.714	0.616	0.393	0.301	0.249	0.194	0.196	0.458
		0.5018	1.419	1.051	0.861	0.751	0.496	0.387	0.325	0.257	0.260	0.570
		0.6319	1.635	1.228	1.017	0.896	0.611	0.487	0.413	0.332	0.335	0.694
		0.7956	1.855	1.410	1.181	1.050	0.738	0.598	0.513	0.419	0.422	0.829
		1.002	2.075	1.594	1.348	1.207	0.871	0.717	0.623	0.516	0.520	0.969
		1.261	2.292	1.776	1.516	1.369	1.013	0.847	0.744	0.625	0.628	1.117
		1.588	2.504	1.957	1.683	1.531	1.159	0.983	0.871	0.741	0.745	1.267
		2	2.708	2.131	1.846	1.690	1.307	1.122	1.005	0.865	0.869	1.419
		2.518	2.902	2.298	2.004	1.846	1.455	1.265	1.142	0.995	0.999	1.569
		3.171	3.084	2.456	2.155	1.995	1.601	1.407	1.281	1.128	1.132	1.717
		3.993	3.250	2.603	2.296	2.136	1.743	1.548	1.419	1.262	1.267	1.860
		5.027	3.402	2.741	2.428	2.269	1.880	1.686	1.556	1.397	1.402	1.998
		6.33	3.531	2.864	2.549	2.391	2.009	1.818	1.689	1.529	1.534	2.128
		7.971	3.642	2.968	2.656	2.500	2.127	1.941	1.814	1.656	1.661	2.249
		10.04	3.746	3.071	2.750	2.597	2.235	2.055	1.932	1.776	1.781	2.356
		12.64	3.813	3.149	2.827	2.678	2.328	2.156	2.037	1.885	1.891	2.455
		15.91	3.850	3.206	2.885	2.741	2.404	2.243	2.129	1.982	1.988	2.536
		20.04	3.806	3.231	2.916	2.779	2.457	2.307	2.199	2.060	2.065	2.594
66191-313	C	0.1	0.155	0.071	0.033	0.018	0.004	0.003	0.003	0.002	0.002	0.022
		0.1259	0.203	0.097	0.047	0.026	0.006	0.004	0.003	0.003	0.003	0.032
		0.1585	0.259	0.128	0.064	0.037	0.009	0.005	0.004	0.004	0.004	0.045
		0.1996	0.326	0.166	0.087	0.052	0.012	0.007	0.006	0.005	0.005	0.062
		0.2514	0.401	0.210	0.115	0.070	0.017	0.010	0.007	0.006	0.006	0.083
		0.3165	0.484	0.261	0.148	0.093	0.023	0.013	0.010	0.008	0.008	0.109
		0.3985	0.575	0.318	0.187	0.121	0.031	0.017	0.013	0.010	0.010	0.141
		0.5018	0.672	0.380	0.231	0.154	0.042	0.023	0.017	0.013	0.013	0.177
		0.6319	0.773	0.446	0.280	0.191	0.055	0.030	0.022	0.017	0.017	0.218
		0.7956	0.879	0.517	0.334	0.234	0.072	0.039	0.028	0.022	0.023	0.264
		1.002	0.986	0.591	0.392	0.281	0.091	0.051	0.037	0.028	0.029	0.314
		1.261	1.095	0.666	0.454	0.333	0.115	0.065	0.047	0.036	0.038	0.368
		1.588	1.204	0.745	0.519	0.389	0.144	0.083	0.061	0.047	0.048	0.426
		2	1.313	0.825	0.587	0.449	0.176	0.104	0.077	0.060	0.061	0.487
		2.518	1.420	0.905	0.657	0.512	0.214	0.130	0.097	0.076	0.078	0.551
		3.171	1.526	0.986	0.729	0.579	0.258	0.160	0.121	0.095	0.098	0.617
		3.993	1.629	1.068	0.803	0.649	0.306	0.196	0.150	0.119	0.122	0.686
		5.027	1.729	1.150	0.879	0.721	0.361	0.238	0.185	0.148	0.152	0.757
		6.33	1.825	1.231	0.955	0.795	0.421	0.286	0.226	0.182	0.187	0.831
		7.971	1.917	1.312	1.032	0.871	0.486	0.341	0.273	0.222	0.228	0.905
		10.04	2.002	1.391	1.108	0.948	0.556	0.402	0.327	0.269	0.276	0.981
		12.64	2.067	1.468	1.184	1.025	0.630	0.468	0.387	0.322	0.329	1.058
		15.91	2.059	1.526	1.255	1.101	0.706	0.540	0.454	0.381	0.389	1.133
		20.04	1.973	1.543	1.299	1.169	0.782	0.614	0.523	0.444	0.453	1.199

Table 10 Average CTR characteristic (If=1-20mA, Vce=1V) calculated on the samples of biasing group "C" for each irradiation step of both references.

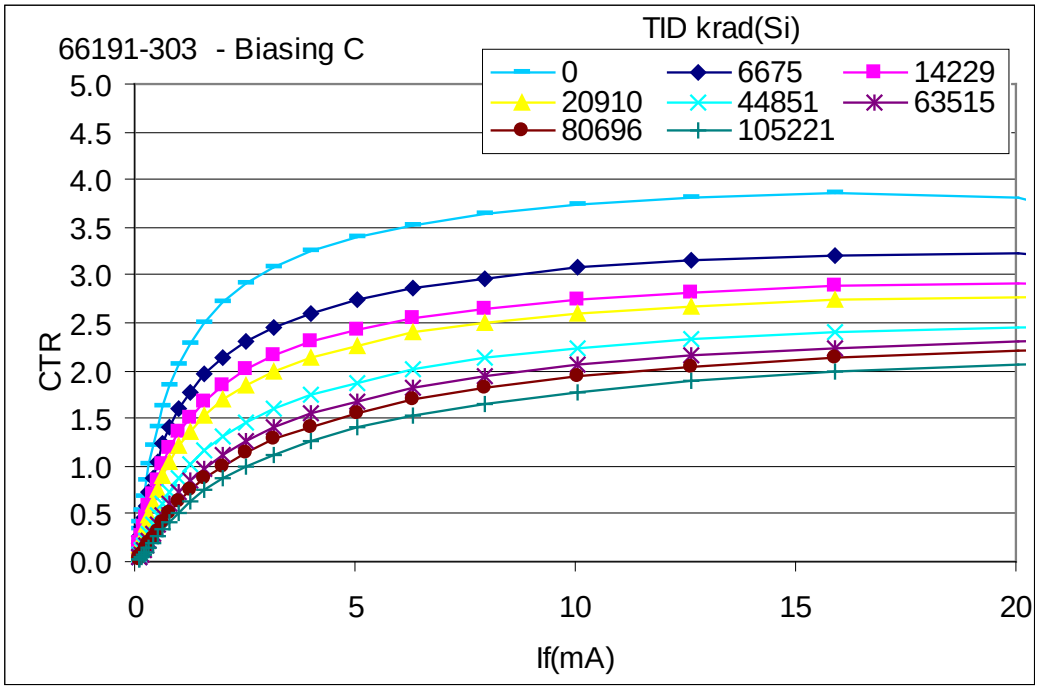


Figure 12: 66191-303 CTR characteristic degradation with TID irradiation (average on samples tested with biasing condition C).

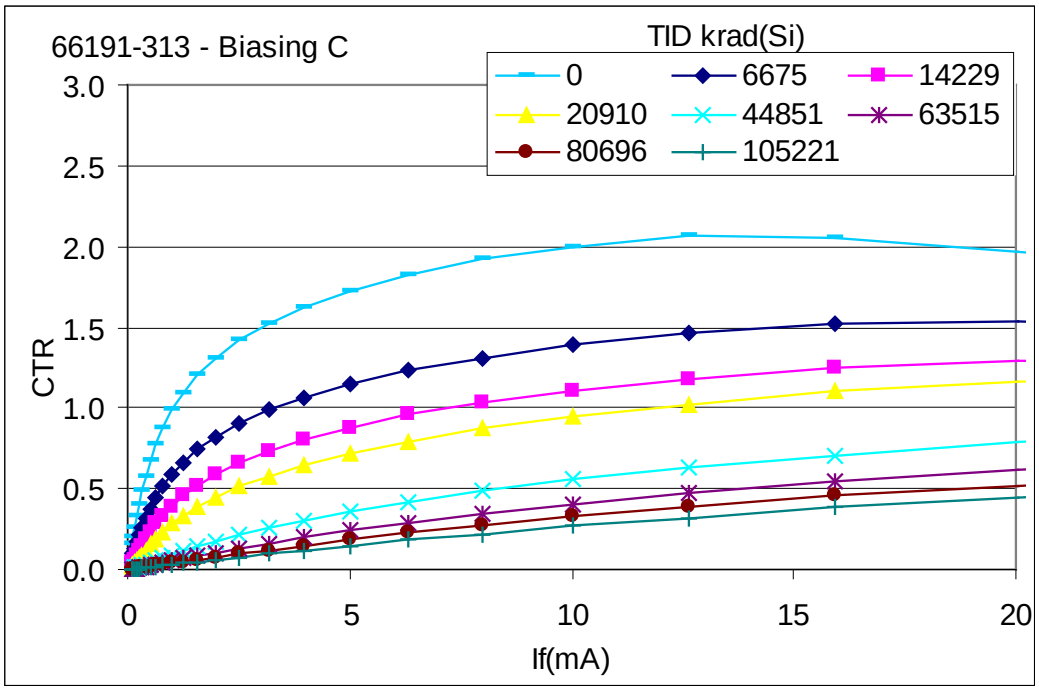


Figure 13: 66191-313 CTR characteristic degradation with TID irradiation (average on samples tested with biasing condition C).

5 DISCUSSION

Due to low sample sizes, the test data was statistically treated employing the one sided tolerance limit method. Parameters employed were 90% probability with 90% confidence. The large part-to-part non-uniformity of the 66191-303 devices significantly impacts the statistical results. The part-to-part non-uniformity of the 66191-313 was less prominent.

Three (3) biasing conditions were employed dictated by ESA mission requirements. The biasing conditions were broadly selected to:

A) Bias the LED and output section of the optocoupler,
B) Bias only the output section of the optocoupler
C) Bias only the optocoupler LED

Due to large part-to-part variation of the 66191-303 it is not clear whether biasing condition A, B or C is worst case. However, the 66191-313 normalised average CTR results, figure 8, weakly indicates that biasing condition C exhibits the highest radiation sensitivity. This conclusion is less clear when taking into account the statistical envelope limits.

Although the average normalised CTR values illustrated in figure 8 show a significant radiation sensitivity increase for the 66191-313 compared to the 66191-303 devices, the difference becomes less significant when accounting for the envelope set by the statistical limits.

Electrical measurements presented in Figure 2 indicate that the pre-irradiation CTR values for the 66191-313 are in average lower than those of the 66191-303 devices. Figure 2 also indicates that the 66191-313 CTR parameters go out of specification with increasing TID exposure. Thus, these measurements support the Alter results and illustrate that the 66191-313 devices are more sensitive to low dose rate TID irradiation than 66191-303 devices.

When considering the CTR values based on statistical limits (figure 7), for bias condition A, the pre-irradiation CTR level is already below manufacturer specification. For bias condition B the CTR value drops below manufacturer specification at about 14krad(Si). For bias condition C the CTR value drops below manufacturer specification between 14 and 20 krad(Si).

The above results are for electrical measurements performed for IF =10mA and Vce =1V. CTR results for other IF values are presented in tables 8 t0 10 and figures 8 to 13.

6 CONCLUSIONS

Low dose rate TID irradiation tests were performed to identify the source of the radiation sensitivity discrepancy observed between 66191-303 (old version) and 66191-313 (new version) devices. According to Micropac the only difference between these devices is the output transistor (from two different manufacturers). Ten (10) parts of each device version were irradiated. These parts were provided to ESA by Micropac. The two device versions were irradiated under the same biasing conditions. Three different biasing conditions based on ESA project requirements were applied.

The irradiation test result illustrate that the 66191-313 (new version) devices are more sensitive to TID radiation than the 66191-303 devices. The part-to-part radiation sensitivity non-uniformity is larger for the 66191-303 devices than those of the 66191-313 devices.

For the worst biasing condition (condition C) the average CTR degradation is worst for the 66191-313, compared to the 66191-303, by approximately 18% at 14krad(Si) and approximately 34% at 100krad(Si). Bias conditions A and B follow a similar trend.

The above results support the need to perform Radiation verification Tests on every optocoupler Flight Model lot planned flown on ESA space missions.

APPENDIX A DATASHEET SPECIFICATIONS

66191 6 PIN LCC RADIATION TOLERANT OPTOCOUPLER

OPTOELECTRONIC PRODUCTS DIVISION

04/21/2009

Features:

- Current transfer ratio: 150% typical
- Base lead provided for conventional transistor biasing
- Low power consumption
- High radiation immunity
- 1000 Vdc isolation test voltage

Applications:

- Military and Space
- High Reliability Systems
- Voltage Level Shifting
- Isolated Receiver Inputs
- Communication Systems

DESCRIPTION

The *66191* Optocoupler consists of a 660 nm GaAlAs LED optically coupled to a photodiode detector driving a radiation tolerant transistor. This configuration has proven to be highly tolerant to both proton and total dose radiation. Radiation tests performed on the 66099 optocoupler have shown that the electrical performance of the device after irradiation is an order of magnitude better than the 4N49 optocouplers. The 66191 has the same components and layout in a 6 pin, hermetically sealed leadless chip carrier package. Available as commercial or screened levels.

ABSOLUTE MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

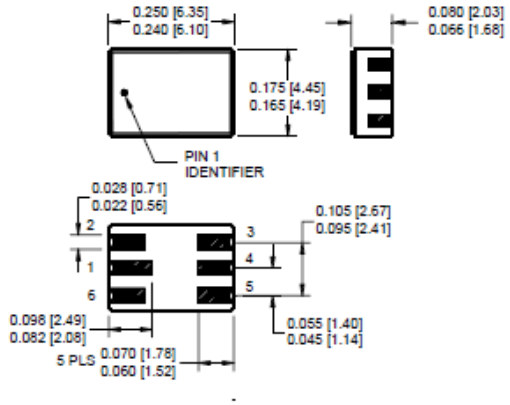
*** Input Diode**

Peak Forward Input Current	50 mA
Reverse Input Voltage	7 V
Input Power Dissipation (Note 2)	80 mW
***Output Photodetector**	
Continuous Collector Current	50 mA
Collector-Emitter Voltage	40 V
Emitter-Collector Voltage	5 V
Collector-Base Voltage	40 V
Power Dissipation. (Note 3)	230 mW
Input to output Isolation Voltage (Note 1)	+1 kVdc
Storage Temperature	-55°C to +150°C
Operating Temperature	-55°C to +100°C
Lead Solder Temperature (10 seconds, 1/16" from case)	240°C

Notes:

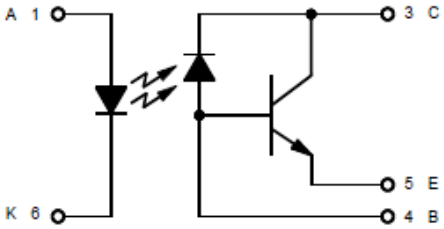
1. Measured with input diode leads shorted together and output leads shorted together
2. Derate linearly 1.0 mW/°C above 25°C.
3. Derate linearly 2.3mW/°C above 25°C.

Package Dimensions



ALL DIMENSIONS ARE IN INCHES [MILLIMETERS]

Schematic Diagram



MICROPAC INDUSTRIES, INC. OPTOELECTRONIC PRODUCTS DIVISION • 725 E.Walnut St., Garland, TX 75040 • (972)272-3571 • Fax (972)487-6918
www.micropac.com E-MAIL: OPTOSALES @ MICROPAC.COM

66191

6 PIN LCC RADIATION TOLERANT OPTOCOUPLER

04/21/2009

ELECTRICAL CHARACTERISTICS

INPUT DIODE

T_A = 25°C unless otherwise specified.

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	TEST CONDITIONS	NOTE
Input Diode Static Reverse Current	I_R			10	µA	V_R = 3V	
Input Diode Static Forward Voltage	V_F	.8	1.8	2	V	I_F = 10mA	

OUTPUT TRANSISTOR

T_A = 25°C unless otherwise specified.

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	TEST CONDITIONS	NOTE
Collector-Base Breakdown Voltage	$V_{(BR)CBO}$	40			V	I_C = 100 µA, I_F = 0	
Collector-Emitter Breakdown Voltage	$V_{(BR)CEO}$	40			V	I_C = 1 mA, I_B = 0, I_F = 0	
Emitter-Collector Breakdown Voltage	$V_{(BR)ECO}$	5			V	I_E = 100 µA, I_F = 0	
Collector-Emitter Dark Current +100°C	I_{CEO}			100 20	nA µA	V_{CE} = 20V	

COUPLED CHARACTERISTICS

T_A = 25°C unless otherwise specified.

PARAMETER	SYMBOL	MIN	TYP	MAX	UNITS	TEST CONDITIONS	NOTE
Current Transfer Ratio	CTR	100			%	V_{CE} = 1 V, I_F = 10 mA	
Collector-Emitter Saturation Voltage	$V_{CE(SAT)}$			0.3	V	I_F = 20 mA, I_C=10 mA	
Input -Output Isolation Voltage	V_{I-O}			1000	V	I_{I-O} = 100 nA	1
Input to Output Capacitance	C_{I-O}		2.5	5	pF	f = 1MHz, V_{I-O} = 1kV	1
Rise Time	t_r			5	µs	V_{CC} = 5 V, I_F = 2 mA, R_L = 100Ω	
Fall Time	t_f			7	µs	V_{CC} = 5 V, I_F = 2 mA, R_L = 100 Ω	

NOTES:

1) These parameters are measured between all phototransistor leads shorted together and with both input diode leads shorted together.

RECOMMENDED OPERATING CONDITIONS:

PARAMETER	SYMBOL	MIN	MAX	UNITS
Input Current, Low Level	I_{FL}	0	100	µA
Input Current, High Level	I_{FH}	10	20	mA
Supply Voltage	V_{CE}	5	20	V
Operating Temperature	T_A	-55	+100	°C

SELECTION GUIDE

PART NUMBER	PART DESCRIPTION
66191-001	Commercial
66191-101	Screened to JAN level
66191-103	Screened to JANTX level
66191-105	Screened to JANTXV level
66191-300	Screened to Space level

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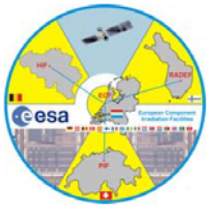
APPENDIX B RADIATION SUMMARY

ESTEC ^{60}Co Facility

Keplerlaan, 1 2200AG Noordwijk ZH (NL)



RADIATION TEST SUMMARY

Irradiation Test Report Number : **20105** *Date :* **28 July 2011**

Test Requester : *Name* ESA
Address TEC-QTC
Personnel present : A Costantino
Project/Cost Code : TRP
Devices/Components irradiated : Opto-Couplers
Device/Component details : Micropac 66191 (types 303 & 313)
(conditions and identification)

Dosimetry Chain used : C
Dosimeter : Farmer model 2680 – s/n 491
Gas Ionisation Chamber : NE Type 2571 – s/n 3573
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 : 43.3TBq *on date :* 06/07/2011

	units	*Min.*	*Max.*	Time-weighted Average
Temperature	°C	*24.2*	*24.7*	24.50
Pressure	mbar	*992.8*	*1019.6*	1009.72
Relative Humidity	%	*37.4*	*43.7*	41.30

Dosimeter position relative to ^{60}Co source		
X	cm	-1
Y	cm	186
Z	cm	10

Run	*Start Date & Time (CET)*	*End Date & Time (CET)*	*Total Ionising Dose [Gy] (water)*	*Dose Rate [Gy/h] (water)*
1	05 Jul 2011 18:09:35	06 Jul 2011 12:39:27	75.00	4.06
2	06 Jul 2011 13:25:53	07 Jul 2011 13:11:17	88.29	3.95
3	07 Jul 2011 13:15:30	08 Jul 2011 08:38:10	76.41	3.94
4	08 Jul 2011 11:36:00	11 Jul 2011 09:10:00	277.00	3.98
5	11 Jul 2011 10:36:06	13 Jul 2011 15:59:55	209.71	3.93
6	13 Jul 2011 16:44:34	15 Jul 2011 15:26:36	180.68	3.93
7	15 Jul 2011 16:46:44	18 Jul 2011 13:40:01	275.56	4.00

Note: *The uncertainty budget associated with the absorbed dose to water measurements is 4.2 % (k=2) according to TEC-QEC/PR001 paragraph 12*

Notes: TID and dose rate figures, expressed in krad and rad/h, are reported, as in *Table 1*, for customer convenience only.

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ESTEC ^{60}Co Facility

Keplerlaan, 1 2200AG Noordwijk ZH (NL)

Table 1 *radiation summary data expressed in rad and rad/h*

Run	*Start Date & Time (CET)*	*End Date & Time (CET)*	*Total Ionising Dose [krad] (water)*	*Dose Rate [rad/h] (water)*
1	05 Jul 2011 18:09:35	06 Jul 2011 12:39:27	7.500	406
2	06 Jul 2011 13:25:53	07 Jul 2011 13:11:17	8.829	395
3	07 Jul 2011 13:15:30	08 Jul 2011 08:38:10	7.641	394
4	08 Jul 2011 11:36:00	11 Jul 2011 09:10:00	27.700	398
5	11 Jul 2011 10:36:06	13 Jul 2011 15:59:55	20.971	393
6	13 Jul 2011 16:44:34	15 Jul 2011 15:26:36	18.068	393
7	15 Jul 2011 16:46:44	18 Jul 2011 13:40:01	27.556	400

Michele Muschitiello
(TEC-QEC Radiation Test Engineer)

Ali Zadeh
(TEC-QEC Section Head)

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