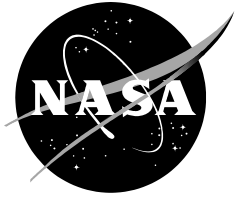


NASA/TM—20220012015



# Displacement Damage Test Report for the 66171 Optocoupler

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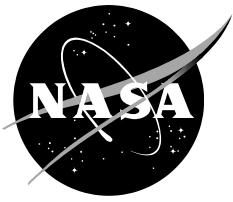
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NASA/TM—20220012015



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Test Date: 11/7/2018

Report Date: 2/5/2019

National Aeronautics and  
Space Administration

Goddard Space Flight Center  
Greenbelt, MD 20771

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**November 2022**

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## I. Introduction

The purpose of this study is to examine the displacement damage susceptibility of the 66171 optically coupled isolator manufactured by Micropac.

## II. Device Description

The 66171 is an optically coupled isolator with four GaAlAs LEDs and four silicon phototransistors. Each unit contains four channels. Table I shows the test and part details. Figure 1 shows the pin configuration of the 20 pin LCC package. The device performance specifications can be found in the manufacturer's datasheet [1].

Table I  
Test and part information.

<b>Generic Part Number</b>	66171
<b>REAG ID</b>	17-047
<b>Manufacturer</b>	Micropac
<b>Lot/Date Code</b>	1751
<b>Quantity tested</b>	10
<b>Part Function</b>	Optocoupler
<b>Package Style</b>	20 pin LCC
<b>Test Engineer</b>	Anthony Phan
<b>Test Equipment</b>	Keithley SMUs

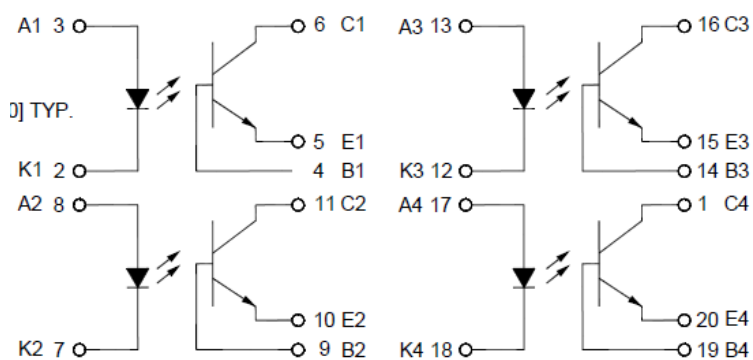


Fig. 1. Pin configuration.

### III. Test Method

#### A. Irradiation Procedure

The irradiation was performed at Crocker Nuclear Laboratory on the campus of The University of California at Davis with a proton energy of 64 MeV. Figure 2 shows the bias circuit during radiation. Table II shows the fluence and total dose steps for each exposure. Four devices were irradiated under bias and four were unbiased. There were two control devices.

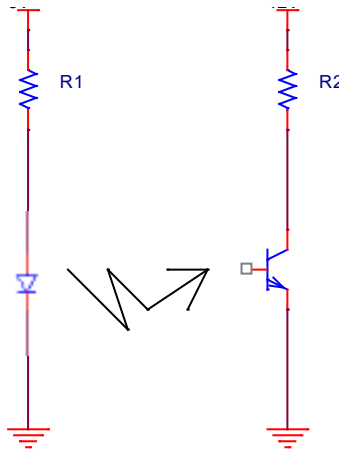


Fig. 2. Schematic diagram of the irradiation bias configuration.

Table II  
Fluence and Total Dose for each exposure.

Run Number	Set of parts	Total Dose (krad-Si)	Per Run Fluence (#/cm <sup>2</sup> )	Total Fluence (#/cm <sup>2</sup> )
1	unbiased	1.25	9.07E+09	9.07E+09
2	biased	1.25	9.08E+09	9.09E+12
3	unbiased	2.5	9.08E+09	2.72E+10
4	biased	2.51	9.12E+09	1.82E+10
5	unbiased	4.42	1.39E+10	3.21E+10
6	biased	4.42	1.39E+10	3.2E+10
7	unbiased	6.63	1.6E+10	4.81 E+10
8	biased	6.63	1.6E+10	4.82 E+10
9	unbiased	8.83	1.6E+10	6.42 E+10
10	biased	8.84	1.6E+10	6.42 E+10
11	unbiased	11	1.6E+10	8.02 E+10
12	biased	11	1.6E+10	8.02 E+10
13	unbiased	15	2.87E+10	1.09 E+11
14	biased	15	2.87E+10	1.09 E+11

### B. Test Conditions

<b>Test temperature:</b>	Room temperature
<b>Test Parameters:</b>	The parameters were measured using the datasheet's test conditions, see Table III.
<b>Measurements:</b>	CTR: $CTR = I_c/I_f$ Forward Voltage ( $V_F$ ) Emitter-Collector Breakdown Voltage ( $V_{(BR)CEO}$ ) On-state Collector Current ( $I_{C(ON)}$ ) Collector-Emitter Saturation Voltage ( $V_{CE(SAT)}$ )

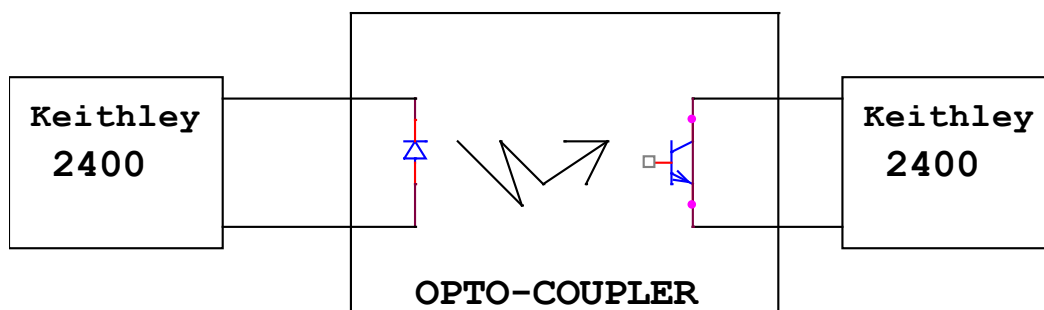


Fig. 3. Block diagram of the test circuit.

Table III  
List of parameters measured.

Symbol	Parameter	MIN	TYP	MAX	Units	Test Conditions
$V_F$	Forward Voltage	0.8		1.8	V	$I_F = 10\text{mA}$
$V_{(BR)CEO}$	Emitter-Collector Breakdown Voltage	40			V	$I_C = 100\mu\text{A}$ , $I_B = 0$ , $I_F = 0$
$I_{C(ON)}$	On-state Collector Current	2		20	mA	$V_{CE} = 5\text{V}$ , $I_F = 1\text{mA}$ , $I_B = 0$
CTR	Current Transfer ratio			20*	-	$V_{CE} = 5\text{V}$ , $I_F = 1\text{mA}$ , $I_B = 0$
$V_{CE(SAT)}$	Collector-Emitter Saturation Voltage			0.3	V	$I_C = 2\text{mA}$ , $I_F = 2\text{mA}$ , $I_B = 0$

\*Calculated from on-state collector current and its forward current test condition.

#### IV. Results

Overall this part performed well over increasing radiation exposure. Only on-state collector current measured below specification starting at the 11 krad(Si) equivalent dose step. This is shown in Figures 4 through 7. CTR also decreased as dose step increased. CTR measurements are shown in Figures 8 through 11. All other parameters stayed well within specifications. Figures 12 through 15 show the emitter-collector breakdown voltage over dose. Figures 16 through 19 show the collector-emitter saturation voltage over dose. Figure 20 shows the forward voltage over dose.

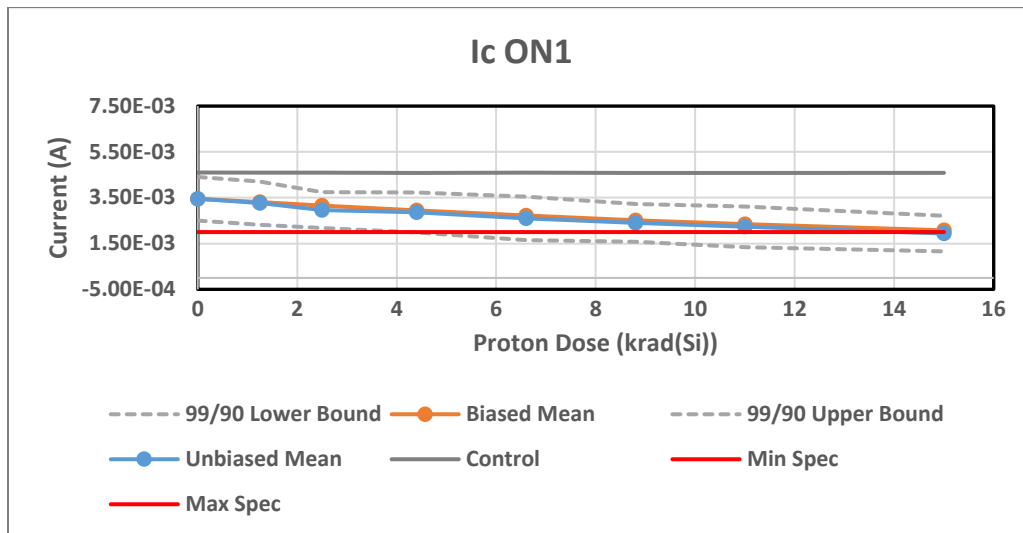


Fig. 4. On-state collector Current1 vs. Dose (krad(Si))

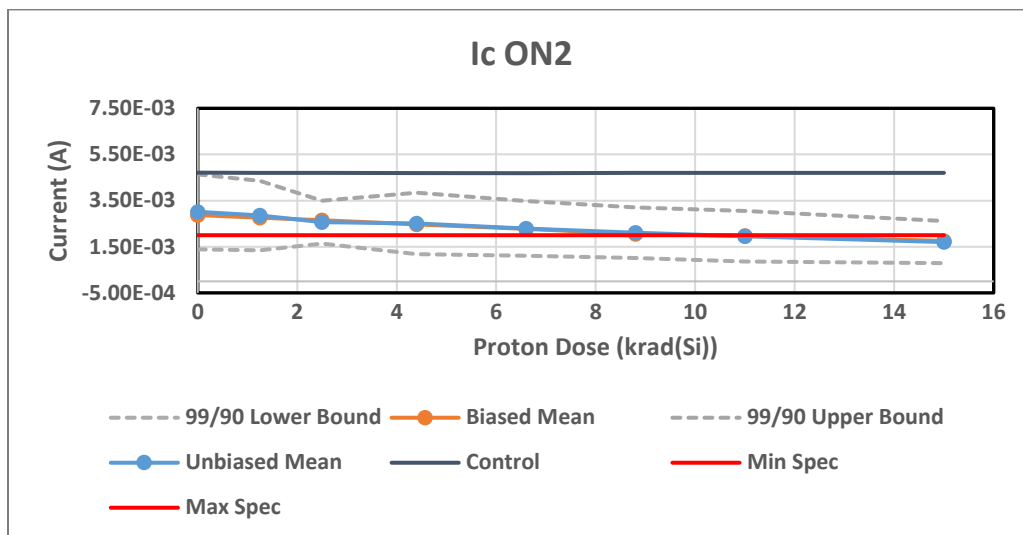


Fig. 5. On-state collector Current2 vs. Dose (krad(Si))



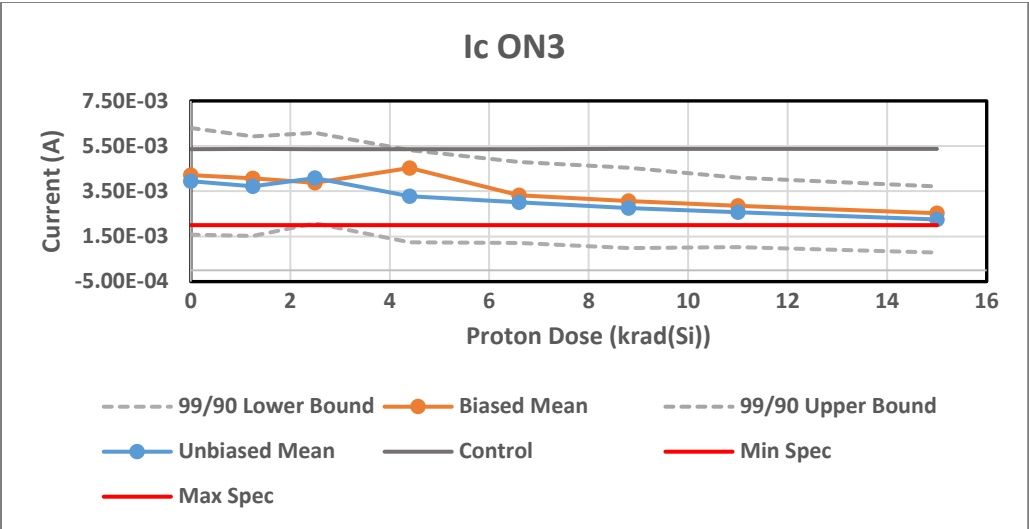


Fig. 6. On-state collector Current3 vs. Dose (krad(Si))

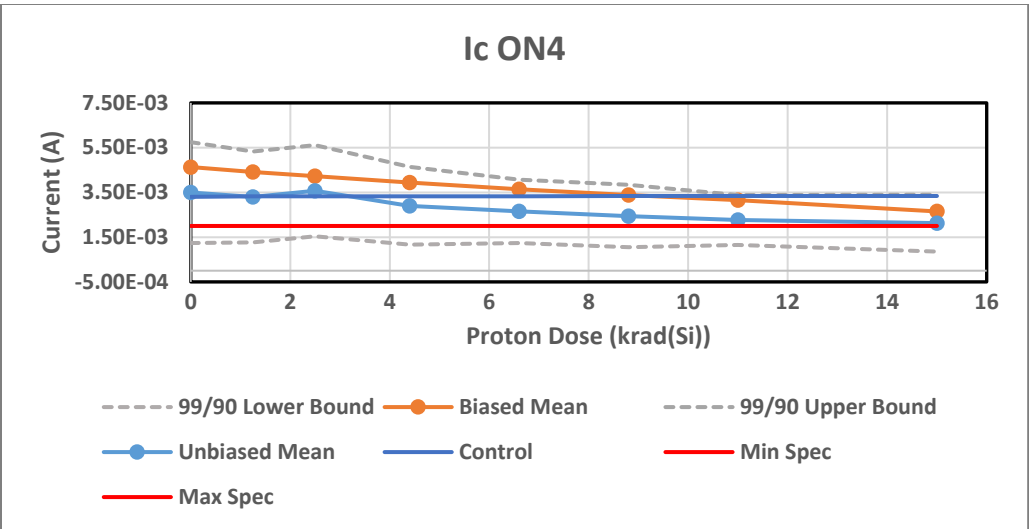


Fig. 7. On-state collector Current4 vs. Dose (krad(Si))

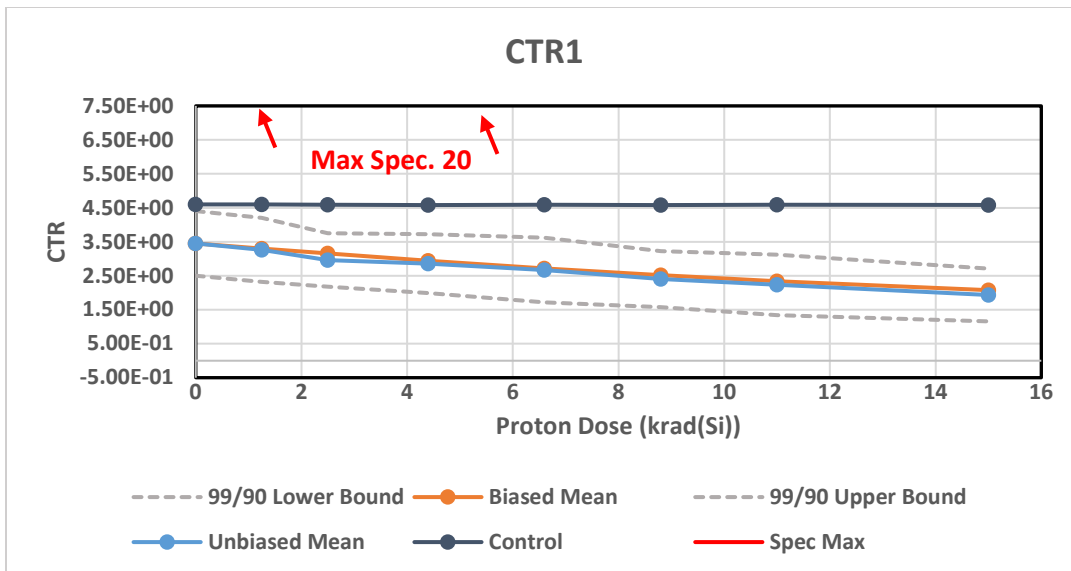


Fig. 8. CTR1 vs. Dose (krad(Si))

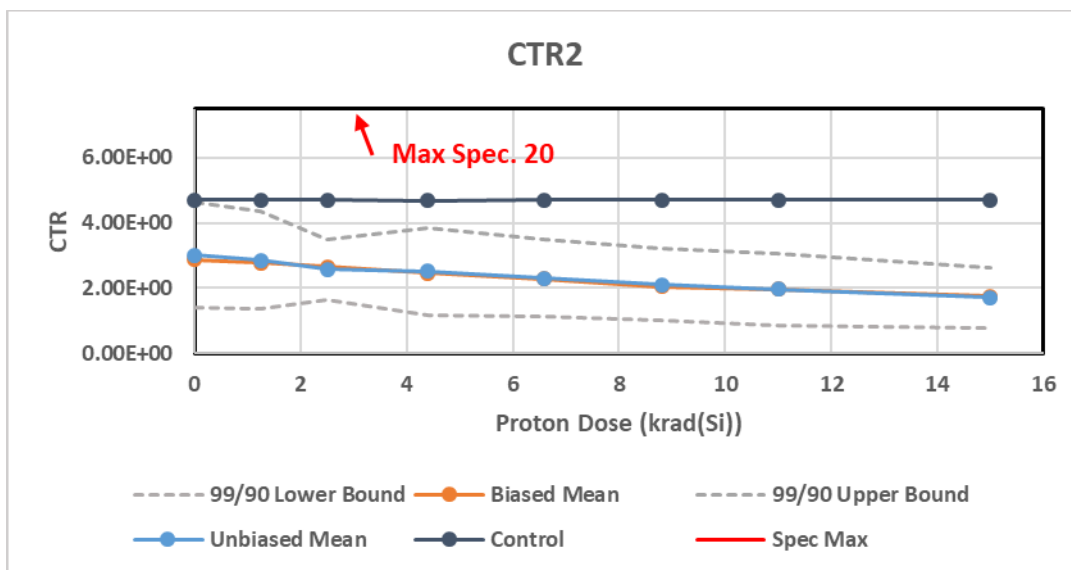


Fig. 9. CTR2 vs. Dose (krad(Si))

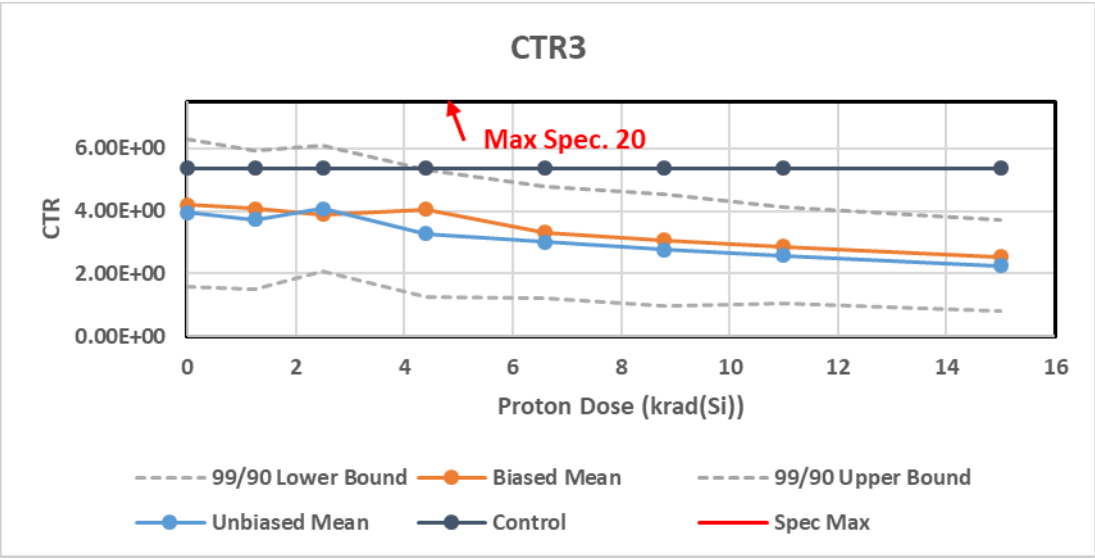


Fig. 10. CTR3 vs. Dose (krad(Si))

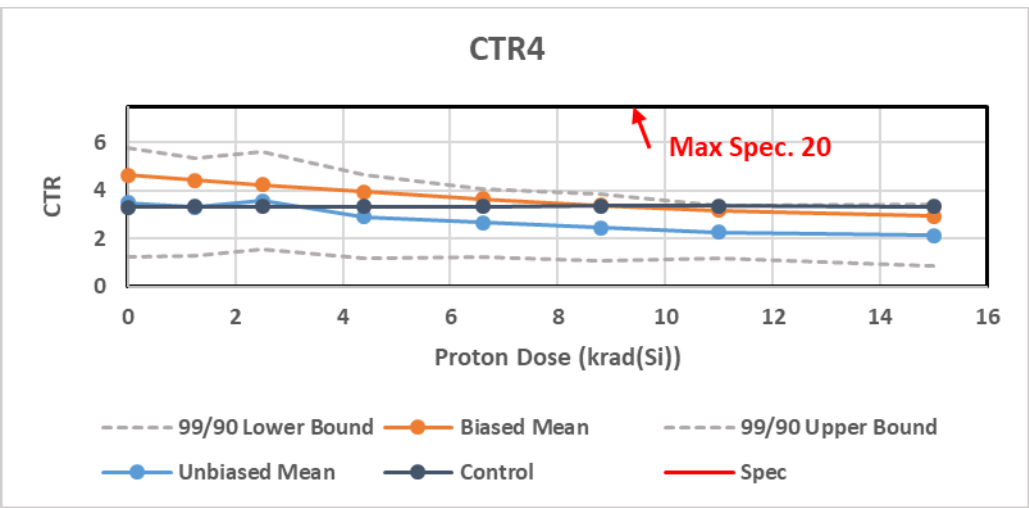


Fig. 11. CTR4 vs. Dose (krad(Si))

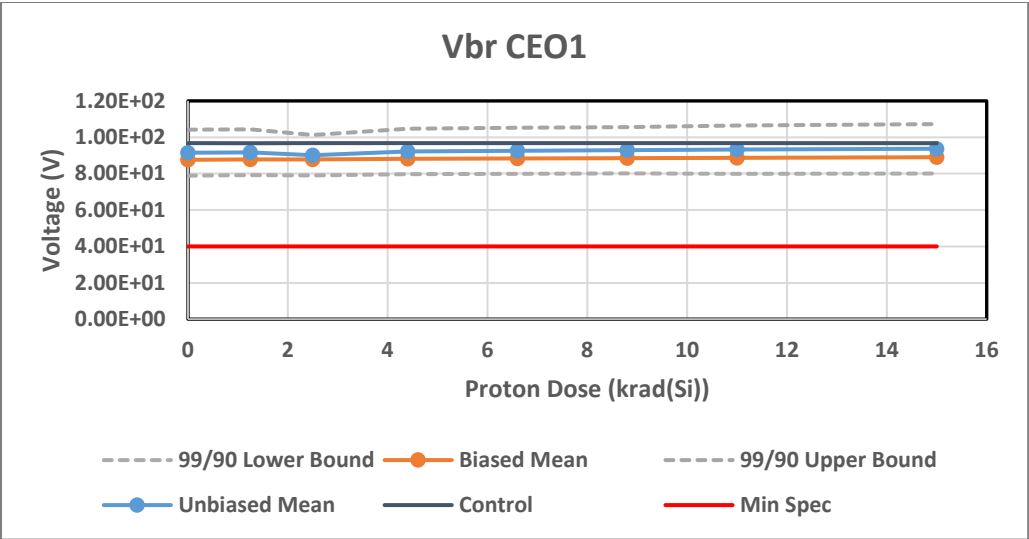


Fig. 12. Collector-Emitter Breakdown Voltage1 vs. Dose (krad(Si))

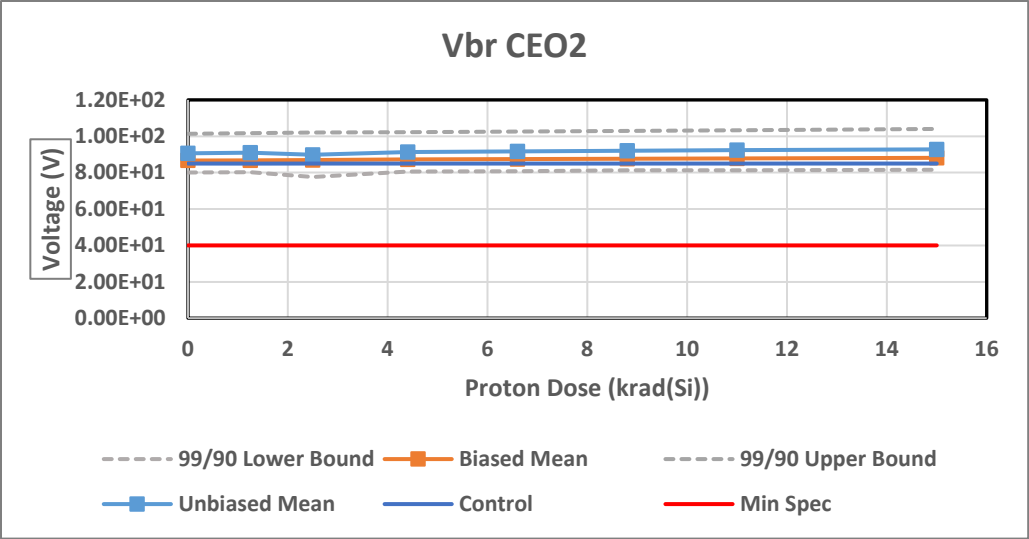


Fig. 13. Collector-Emitter Breakdown Voltage2 vs. Dose (krad(Si))

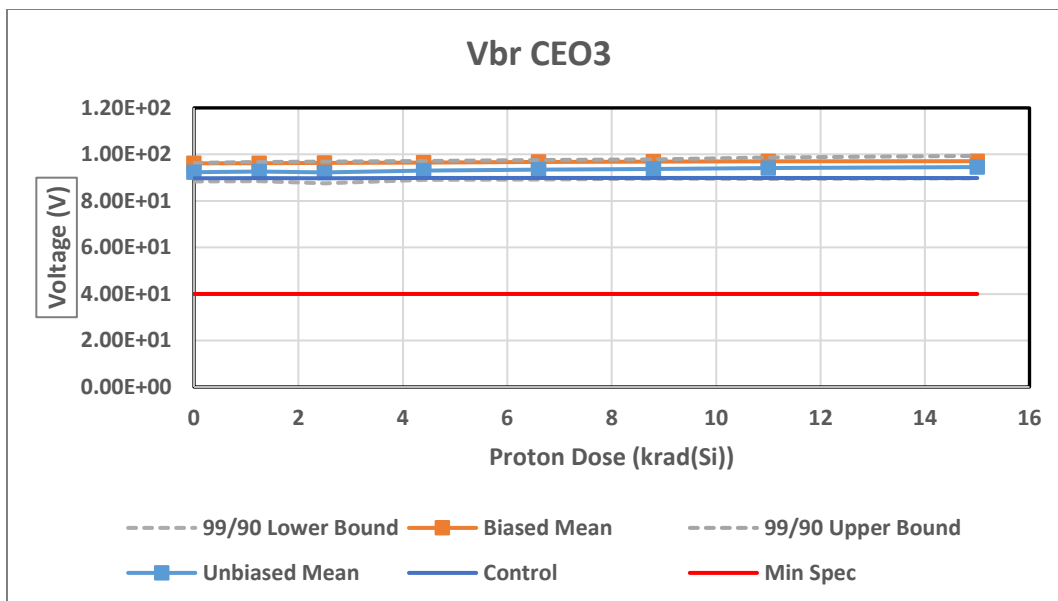


Fig. 14. Collector-Emitter Breakdown Voltage3 vs. Dose (krad(Si))

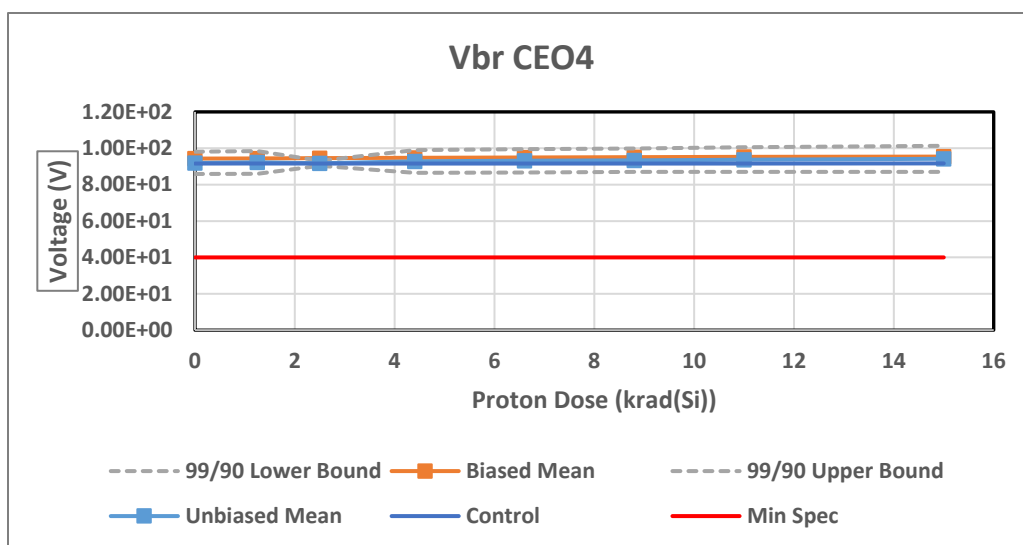


Fig. 15. Collector-Emitter Breakdown Voltage4 vs. Dose (krad(Si))

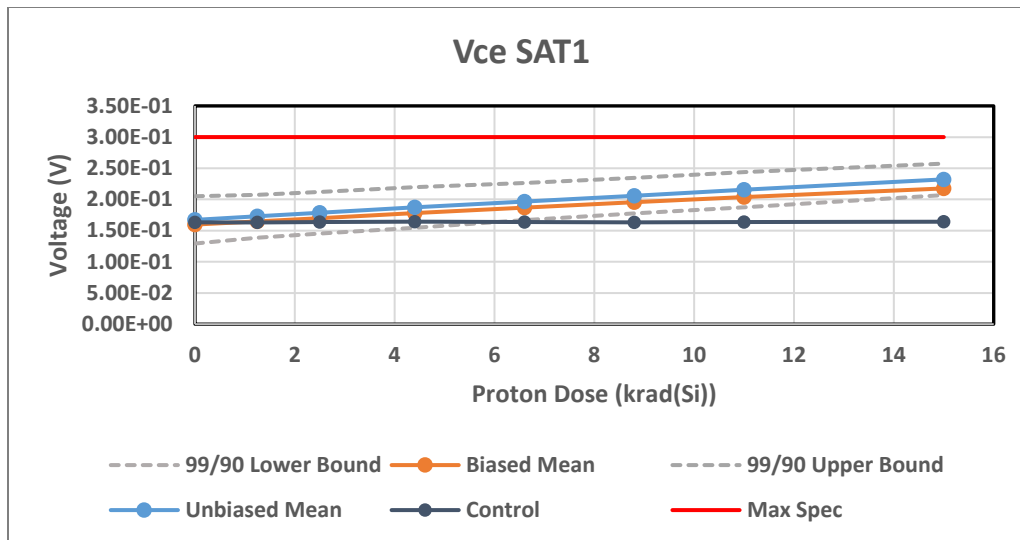


Fig. 16. Collector-Emitter Saturation Voltage1 vs. Dose (krad(Si))

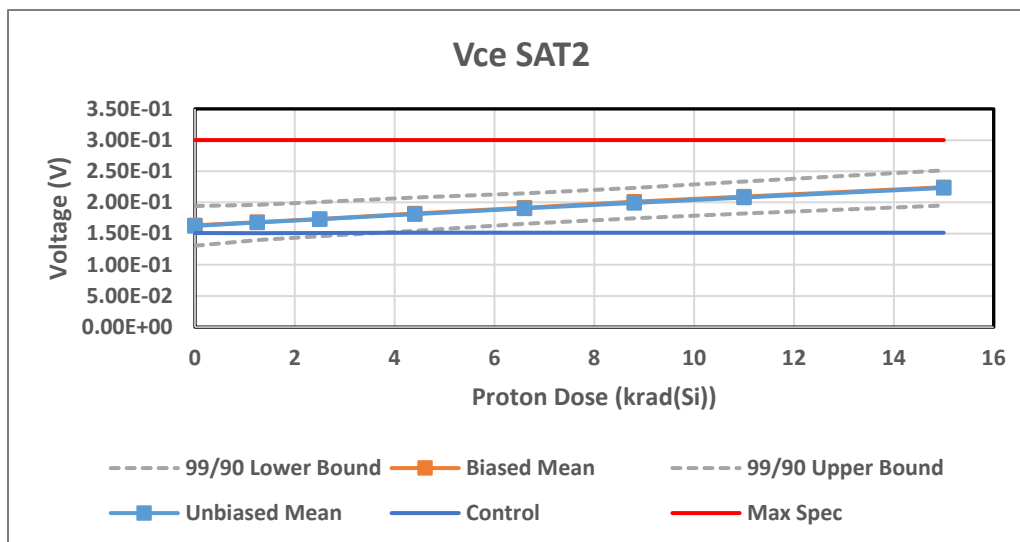


Fig. 17. Collector-Emitter Saturation Voltage2 vs. Dose (krad(Si))

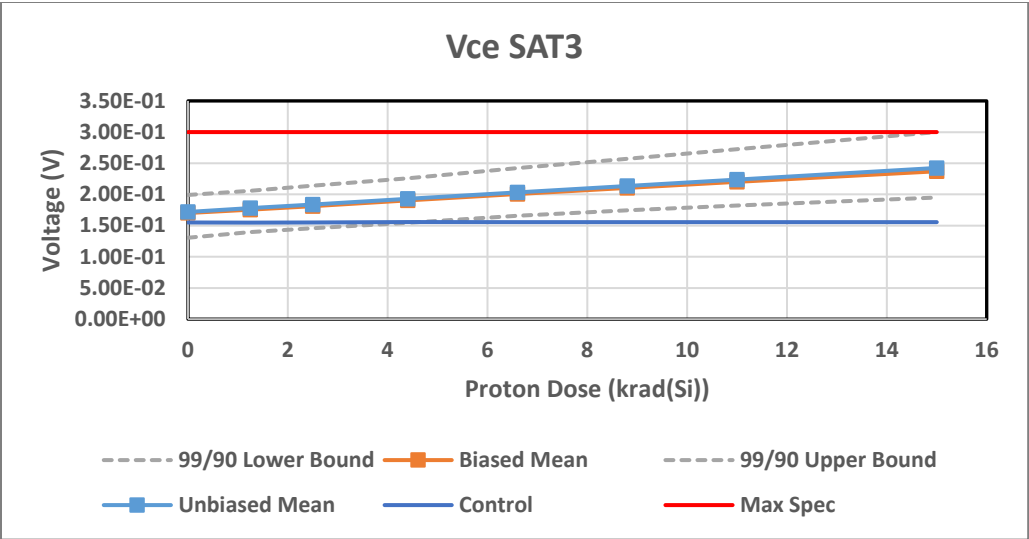


Fig. 18. Collector-Emitter Saturation Voltage3 vs. Dose (krad(Si))

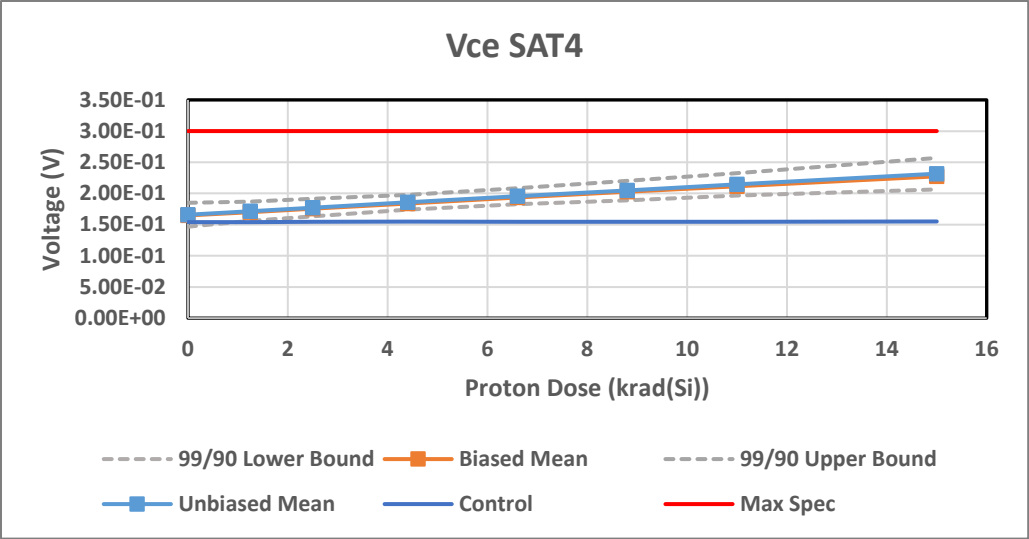


Fig. 19. Collector-Emitter Saturation Voltage4 vs. Dose (krad(Si))

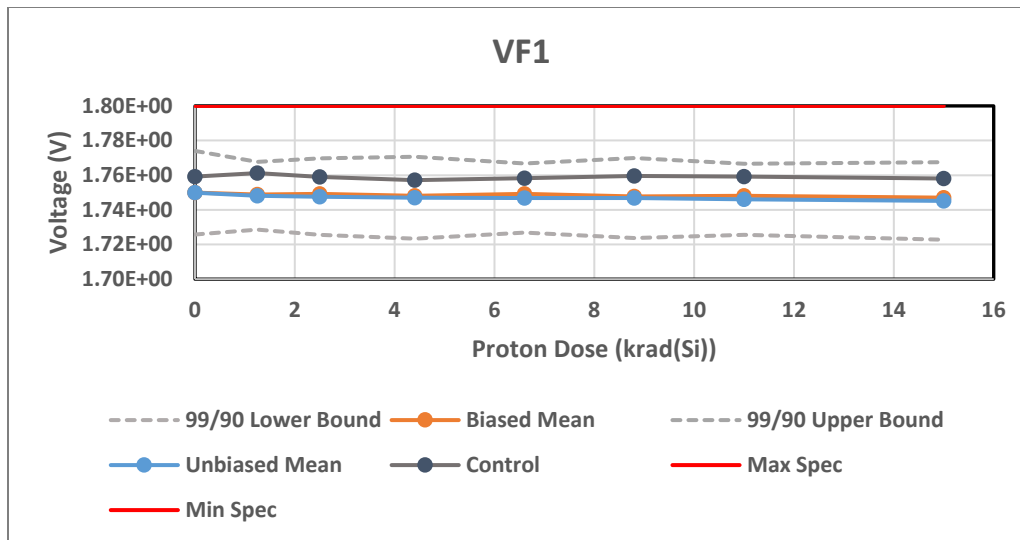


Fig. 20. Forward Voltage1 vs. Dose (krad(Si))

## V. Reference

- [1] Micropac, “<http://micropac.com/images/DataSheet/66171.pdf>” datasheet, Mar. 15, 2017



## Appendix

### A. Raw Data (Summary)

CTR1 Dose (krad(Si))	Biased			Unbiased			Control	Spec
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Max
0	7.95E-01	3.45E+00	6.11E+00	2.50E+00	3.45E+00	4.404619	4.600193	20
1.25	7.70E-01	3.30E+00	5.84E+00	2.32E+00	3.262226	4.20E+00	4.595481	20
2.5	7.67E-01	3.16E+00	5.55E+00	2.18E+00	2.96E+00	3.75E+00	4.590673	20
4.4	7.29E-01	2.94E+00	5.157787	1.99E+00	2.86E+00	3.72E+00	4.584948	20
6.6	6.80E-01	2.716833	4.75E+00	1.719463919	2.67E+00	3.62E+00	4.588868	20
8.8	6.13E-01	2.52E+00	4.42E+00	1.58E+00	2.40E+00	3.23E+00	4.585725	20
11	5.81E-01	2.34E+00	4.11E+00	1.34E+00	2.231293	3.12E+00	4.587175	20
15	4.98E-01	2.08E+00	3.66E+00	1.16E+00	<b>1.93E+00</b>	2.71E+00	4.584564	20

CTR2 Dose (krad(Si))	Biased			Unbiased			Control	Spec
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Max
0	7.65E-01	2.87E+00	4.98E+00	1.39E+00	3.01E+00	4.64E+00	4.711694	20
1.25	7.24E-01	2.764719	4.81E+00	1.35E+00	2.85E+00	4.36E+00	4.704575	20
2.5	6.72E-01	2.64E+00	4.62E+00	1.64E+00	2.57E+00	3.49E+00	4.698107	20
4.4	6.03E-01	2.47E+00	4.33E+00	1.18E+00	2.51E+00	3.84E+00	4.693758	20
6.6	5.47E-01	2.275871	4.01E+00	1.12E+00	2.30E+00	3.47E+00	4.694354	20
8.8	1.99E-01	2.05E+00	3.90E+00	1.02E+00	2.107295	3.20E+00	4.699309	20
11	4.14E-01	<b>1.97E+00</b>	3.53E+00	0.858662916	<b>1.957559</b>	3.06E+00	4.702553	20
15	3.38E-01	<b>1.753696</b>	3.17E+00	7.89E-01	<b>1.70E+00</b>	2.61E+00	4.698176	20

CTR3 Dose (krad(Si))	Biased			Unbiased			Control	Spec
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Max
0	-1.72E+00	4.21E+00	1.01E+01	1.58E+00	3.94E+00	6.30E+00	5.367251	20
1.25	-1.2921577	4.066931	9.42602	1.518416038	3.722737	5.927057	5.373695	20
2.5	-1.19187029	3.881439	8.954747	2.07987756	4.083743	6.087608	5.362471	20
4.4	0.26495398	4.056355	7.847755	1.242476247	3.283903	5.32533	5.363813	20
6.6	-1.00539639	3.318812	7.64302	1.21620161	3.006465	4.796727	5.366328	20
8.8	-0.9277783	3.068583	7.064943	0.977895389	2.760478	4.543061	5.372789	20
11	-0.875865	2.858018	6.5919	1.028701159	2.567822	4.106943	5.37272	20
15	-0.76796123	2.52795	5.823862	0.786455474	2.249394	3.712332	5.369615	20

CTR4 Dose (krad(Si))	Biased			Unbiased			Control	Spec
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Max
0	-2.29510746	4.63263	11.56037	1.241413364	3.493173	5.744932	3.301308	20
1.25	-2.16414126	4.41849	11.00112	1.258713771	3.294477	5.330239	3.326952	20
2.5	-2.11019454	4.22529	10.56077	1.53777612	3.572814	5.607852	3.322226	20
4.4	-2.01081338	3.940912	9.892636	1.161024879	2.900497	4.63997	3.330139	20
6.6	-1.93103224	3.645402	9.221837	1.242716057	2.656867	4.071017	3.33196	20
8.8	-1.84418261	3.384562	8.613307	1.050967534	2.441824	3.83268	3.339614	20
11	-1.78786842	3.154827	8.097522	1.154270566	2.267451	3.380631	3.338704	20
15	-2.39361973	2.9253	8.24422	0.853327591	2.126917	3.400505	3.334571	20

Ic ON1 Dose (krad(Si))	Biased			Unbiased			Control	Spec	
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	Max
0	7.94E-04	0.003451	6.11E-03	2.50E-03	3.45E-03	4.41E-03	4.60E-03	2.00E-03	2.00E-02
1.25	7.69E-04	0.003304	5.84E-03	2.32E-03	3.26E-03	4.20E-03	0.004596	2.00E-03	2.00E-02
2.5	7.67E-04	0.003157	5.55E-03	2.18E-03	2.96E-03	3.75E-03	0.004591	2.00E-03	2.00E-02
4.4	7.29E-04	0.002944	5.16E-03	1.99E-03	2.86E-03	3.72E-03	0.004585	2.00E-03	2.00E-02
6.6	6.81E-04	0.002717	4.75E-03	1.65E-03	0.0026	3.55E-03	0.004589	2.00E-03	2.00E-02
8.8	6.12E-04	0.002516	4.42E-03	1.58E-03	0.002403	3.23E-03	0.004586	2.00E-03	2.00E-02
11	5.81E-04	0.002344	4.11E-03	1.34E-03	0.002231	3.12E-03	0.004587	2.00E-03	2.00E-02
15	4.98E-04	0.002077	3.66E-03	1.16E-03	<b>0.001935</b>	2.71E-03	0.004585	2.00E-03	2.00E-02

Ic ON2 Dose (krad(Si))	Biased			Unbiased			Control	Spec	
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	Max
0	7.65E-04	2.87E-03	4.98E-03	1.39E-03	3.01E-03	4.64E-03	4.71E-03	2.00E-03	2.00E-02
1.25	7.24E-04	2.76E-03	4.81E-03	1.35E-03	2.85E-03	4.36E-03	0.004705	2.00E-03	2.00E-02
2.5	6.72E-04	2.64E-03	4.62E-03	1.64E-03	2.57E-03	3.49E-03	0.004699	2.00E-03	2.00E-02
4.4	6.03E-04	2.47E-03	4.33E-03	1.17E-03	2.51E-03	3.84E-03	0.004694	2.00E-03	2.00E-02
6.6	5.47E-04	0.002276	4.01E-03	1.12E-03	2.30E-03	3.47E-03	0.004695	2.00E-03	2.00E-02
8.8	1.99E-04	2.05E-03	3.90E-03	1.02E-03	2.11E-03	3.20E-03	0.0047	2.00E-03	2.00E-02
11	4.13E-04	<b>1.97E-03</b>	3.53E-03	8.59E-04	<b>0.001958</b>	3.06E-03	0.004703	2.00E-03	2.00E-02
15	3.38E-04	<b>1.75E-03</b>	3.17E-03	7.89E-04	<b>1.70E-03</b>	2.62E-03	0.004698	2.00E-03	2.00E-02

Ic ON3 Dose (krad(Si))	Biased			Unbiased			Control	Spec	
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	Max
0	-1.72E-03	4.21E-03	1.01E-02	1.58E-03	3.94E-03	6.30E-03	5.37E-03	2.00E-03	2.00E-02
1.25	-1.29E-03	4.07E-03	9.43E-03	1.52E-03	0.003723	5.93E-03	0.005374	2.00E-03	2.00E-02
2.5	-1.19E-03	3.88E-03	8.95E-03	2.08E-03	4.08E-03	6.09E-03	0.005363	2.00E-03	2.00E-02
4.4	-3.49E-04	4.53E-03	9.41E-03	1.24E-03	3.28E-03	5.33E-03	0.005364	2.00E-03	2.00E-02
6.6	-1.01E-03	0.003319	7.64E-03	1.22E-03	3.01E-03	4.80E-03	0.005367	2.00E-03	2.00E-02
8.8	-9.28E-04	3.07E-03	7.07E-03	9.79E-04	2.76E-03	4.54E-03	0.005373	2.00E-03	2.00E-02
11	-8.77E-04	2.86E-03	6.59E-03	1.03E-03	0.002568	4.11E-03	0.005373	2.00E-03	2.00E-02
15	-7.68E-04	2.53E-03	5.82E-03	7.86E-04	2.25E-03	3.71E-03	0.00537	2.00E-03	2.00E-02

Ic ON4 Dose (krad(Si))	Biased			Unbiased			Control	Spec	
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	Max
0	-2.29E-03	4.63E-03	1.16E-02	1.24E-03	3.49E-03	5.74E-03	3.30E-03	2.00E-03	2.00E-02
1.25	-2.16E-03	4.42E-03	1.10E-02	1.26E-03	3.29E-03	5.33E-03	0.003327	2.00E-03	2.00E-02
2.5	-2.11E-03	4.23E-03	1.06E-02	1.54E-03	3.57E-03	5.61E-03	0.003322	2.00E-03	2.00E-02
4.4	-2.01E-03	3.94E-03	9.89E-03	1.16E-03	2.90E-03	4.64E-03	0.00333	2.00E-03	2.00E-02
6.6	-1.93E-03	0.003646	9.22E-03	1.24E-03	2.66E-03	4.07E-03	0.003332	2.00E-03	2.00E-02
8.8	-1.84E-03	3.38E-03	8.61E-03	1.05E-03	2.44E-03	3.83E-03	0.00334	2.00E-03	2.00E-02
11	-1.79E-03	3.15E-03	8.10E-03	1.15E-03	0.002267	3.38E-03	0.003339	2.00E-03	2.00E-02
15	-2.22E-03	2.65E-03	7.52E-03	8.54E-04	2.13E-03	3.40E-03	0.003335	2.00E-03	2.00E-02

VBR CEO1		Biased			Unbiased			Control	Spec
Dose (krad(Si))	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	
0	6.56E+01	8.76E+01	1.10E+02	7.89E+01	9.15E+01	104.1568	96.73272	40	
1.25	6.57E+01	8.78E+01	1.10E+02	7.91E+01	91.76758	1.04E+02	96.72274	40	
2.5	6.59E+01	8.79E+01	1.10E+02	7.90E+01	9.01E+01	1.01E+02	96.74234	40	
4.4	6.62E+01	8.81E+01	110.0416	7.97E+01	9.22E+01	1.05E+02	96.75569	40	
6.6	6.64E+01	88.3711	1.10E+02	79.87659589	9.26E+01	1.05E+02	96.74739	40	
8.8	6.66E+01	8.86E+01	1.11E+02	8.02E+01	9.29E+01	1.06E+02	96.73542	40	
11	6.66E+01	8.88E+01	1.11E+02	8.00E+01	93.21142	1.06E+02	96.74163	40	
15	6.69E+01	8.90E+01	1.11E+02	8.01E+01	9.37E+01	1.07E+02	96.7566	40	

VBR CEO2		Biased			Unbiased			Control	Spec
Dose (krad(Si))	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	
0	7.36E+01	8.67E+01	9.97E+01	8.00E+01	9.07E+01	101.3692	84.97428	40	
1.25	7.40E+01	8.68E+01	9.97E+01	8.02E+01	90.92456	1.02E+02	84.97365	40	
2.5	7.40E+01	8.70E+01	1.00E+02	7.76E+01	8.98E+01	1.02E+02	84.9895	40	
4.4	7.41E+01	8.72E+01	100.2845	8.07E+01	9.14E+01	1.02E+02	85.00493	40	
6.6	7.46E+01	87.44719	1.00E+02	80.85030744	9.17E+01	1.03E+02	84.99923	40	
8.8	7.47E+01	8.77E+01	1.01E+02	8.12E+01	9.21E+01	1.03E+02	84.99557	40	
11	7.49E+01	8.78E+01	1.01E+02	8.14E+01	92.36542	1.03E+02	84.98957	40	
15	7.52E+01	8.81E+01	1.01E+02	8.16E+01	9.28E+01	1.04E+02	85.0085	40	

VBR CEO3		Biased			Unbiased			Control	Spec
Dose (krad(Si))	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	
0	8.08E+01	9.62E+01	1.12E+02	8.84E+01	9.24E+01	96.34573	89.80453	40	
1.25	8.10E+01	9.63E+01	1.12E+02	8.85E+01	92.6091	9.67E+01	89.79471	40	
2.5	8.14E+01	9.64E+01	1.11E+02	8.76E+01	9.23E+01	9.70E+01	89.80759	40	
4.4	8.18E+01	9.65E+01	111.2296	8.90E+01	9.31E+01	9.72E+01	89.83485	40	
6.6	8.22E+01	96.70949	1.11E+02	89.2073028	9.34E+01	9.76E+01	89.82537	40	
8.8	8.27E+01	9.69E+01	1.11E+02	8.96E+01	9.37E+01	9.78E+01	89.82484	40	
11	8.30E+01	9.70E+01	1.11E+02	8.95E+01	94.08248	9.87E+01	89.82815	40	
15	8.37E+01	9.71E+01	1.10E+02	8.97E+01	9.46E+01	9.94E+01	89.83497	40	

VBR CEO4		Biased			Unbiased			Control	Spec
Dose (krad(Si))	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	
0	7.87E+01	9.43E+01	1.10E+02	8.59E+01	9.20E+01	98.18523	91.64049	40	
1.25	7.91E+01	9.45E+01	1.10E+02	8.60E+01	92.26163	9.85E+01	91.63187	40	
2.5	7.95E+01	9.46E+01	1.10E+02	9.04E+01	9.18E+01	9.32E+01	91.65105	40	
4.4	8.00E+01	9.47E+01	109.4041	8.65E+01	9.28E+01	9.90E+01	91.66857	40	
6.6	8.07E+01	94.91514	1.09E+02	86.66862765	9.31E+01	9.96E+01	91.66511	40	
8.8	8.13E+01	9.51E+01	1.09E+02	8.70E+01	9.34E+01	9.98E+01	91.6692	40	
11	8.18E+01	9.52E+01	1.09E+02	8.70E+01	93.75278	1.01E+02	91.66099	40	
15	8.25E+01	9.54E+01	1.08E+02	8.71E+01	9.42E+01	1.01E+02	91.67932	40	

VCE SAT1		Biased			Unbiased			Control	Spec
Dose									
(krad(Si))	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Max	
0	1.19E-01	1.60E-01	2.00E-01	1.29E-01	1.67E-01	0.205146	0.163479	0.3	
1.25	1.21E-01	1.65E-01	2.08E-01	1.39E-01	1.73E-01	2.07E-01	0.163094	0.3	
2.5	1.23E-01	1.70E-01	2.17E-01	1.45E-01	1.79E-01	2.12E-01	0.163639	0.3	
4.4	1.26E-01	1.78E-01	0.229601	1.55E-01	1.87E-01	2.20E-01	0.164406	0.3	
6.6	1.30E-01	1.87E-01	2.43E-01	0.166985572	1.97E-01	2.26E-01	0.163645	0.3	
8.8	1.34E-01	1.96E-01	2.58E-01	1.77E-01	2.06E-01	2.34E-01	0.163489	0.3	
11	1.36E-01	2.04E-01	2.72E-01	1.87E-01	2.16E-01	2.44E-01	0.163639	0.3	
15	1.40E-01	2.18E-01	2.95E-01	2.07E-01	2.32E-01	2.57E-01	0.164093	0.3	

VCE SAT2		Biased			Unbiased			Control	Spec
Dose									
(krad(Si))	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Max	
0	1.12E-01	1.63E-01	2.14E-01	1.31E-01	1.62E-01	0.194306	1.51E-01	0.3	
1.25	1.13E-01	1.68E-01	2.23E-01	1.40E-01	1.68E-01	1.96E-01	0.150726	0.3	
2.5	1.16E-01	1.74E-01	2.31E-01	1.46E-01	1.73E-01	2.01E-01	0.151112	0.3	
4.4	1.19E-01	1.82E-01	0.245603	1.54E-01	1.81E-01	2.08E-01	0.151573	0.3	
6.6	1.22E-01	1.92E-01	2.61E-01	0.165747569	1.90E-01	2.15E-01	0.151234	0.3	
8.8	1.24E-01	2.01E-01	2.78E-01	1.75E-01	1.99E-01	2.23E-01	0.151233	0.3	
11	1.28E-01	2.09E-01	2.91E-01	1.82E-01	2.08E-01	2.34E-01	0.151303	0.3	
15	1.32E-01	2.24E-01	3.17E-01	1.95E-01	2.23E-01	2.51E-01	0.151529	0.3	

VCE SAT3		Biased			Unbiased			Control	Spec
Dose									
(krad(Si))	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Max	
0	1.53E-01	1.70E-01	1.87E-01	1.45E-01	1.72E-01	0.199209	1.55E-01	0.3	
1.25	1.56E-01	1.76E-01	1.95E-01	1.50E-01	1.78E-01	2.06E-01	0.154833	0.3	
2.5	1.60E-01	1.81E-01	2.03E-01	1.54E-01	1.84E-01	2.14E-01	0.155265	0.3	
4.4	1.66E-01	1.91E-01	0.214639	1.60E-01	1.93E-01	2.26E-01	0.155736	0.3	
6.6	1.73E-01	2.01E-01	2.28E-01	0.164615466	2.03E-01	2.42E-01	0.155415	0.3	
8.8	1.80E-01	2.11E-01	2.41E-01	1.70E-01	2.13E-01	2.57E-01	0.155374	0.3	
11	1.83E-01	2.20E-01	2.58E-01	1.76E-01	2.24E-01	2.72E-01	0.155466	0.3	
15	1.89E-01	2.37E-01	2.85E-01	1.85E-01	2.43E-01	3.00E-01	0.155699	0.3	

VCE SAT4		Biased			Unbiased			Control	Spec
Dose									
(krad(Si))	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Max	
0	1.35E-01	1.65E-01	1.95E-01	1.47E-01	1.66E-01	0.184981	1.54E-01	0.3	
1.25	1.44E-01	1.70E-01	1.96E-01	1.56E-01	1.72E-01	1.87E-01	0.153984	0.3	
2.5	1.47E-01	1.75E-01	2.04E-01	1.63E-01	1.77E-01	1.91E-01	0.154427	0.3	
4.4	1.53E-01	1.84E-01	0.215078	1.74E-01	1.86E-01	1.98E-01	0.15485	0.3	
6.6	1.59E-01	1.93E-01	2.27E-01	0.182627305	1.95E-01	2.08E-01	0.154524	0.3	
8.8	1.66E-01	2.03E-01	2.40E-01	1.89E-01	2.05E-01	2.20E-01	0.154514	0.3	
11	1.71E-01	2.12E-01	2.53E-01	1.97E-01	2.14E-01	2.32E-01	0.154611	0.3	
15	1.79E-01	2.27E-01	2.76E-01	2.06E-01	2.32E-01	2.57E-01	0.154829	0.3	



VF1 Dose (krad(Si))	Biased			Unbiased			Control	Spec	
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	Max
0	1.72E+00	1.75E+00	1.78E+00	1.73E+00	1.75E+00	1.774019	1.76E+00	0.8	1.8
1.25	1.72E+00	1.75E+00	1.78E+00	1.73E+00	1.748129	1.77E+00	1.761229	0.8	1.8
2.5	1.71E+00	1.75E+00	1.78E+00	1.73E+00	1.75E+00	1.77E+00	1.759048	0.8	1.8
4.4	1.71E+00	1.75E+00	1.783074	1.72E+00	1.75E+00	1.77E+00	1.757157	0.8	1.8
6.6	1.72E+00	1.749219	1.78E+00	1.726863182	1.75E+00	1.77E+00	1.758204	0.8	1.8
8.8	1.71E+00	1.75E+00	1.78E+00	1.72E+00	1.75E+00	1.77E+00	1.759506	0.8	1.8
11	1.72E+00	1.75E+00	1.78E+00	1.73E+00	1.746072	1.77E+00	1.759175	0.8	1.8
15	1.71E+00	1.75E+00	1.78E+00	1.72E+00	1.75E+00	1.77E+00	1.758158	0.8	1.8

VF2 Dose (krad(Si))	Biased			Unbiased			Control	Spec	
	99LL	Mean	99UL	99LL	Mean	99UL	Mean	Min	Max
0	1.73E+00	1.76E+00	1.79E+00	1.74E+00	1.75E+00	1.758211	1.75E+00	0.8	1.8
1.25	1.72E+00	1.76E+00	1.79E+00	1.74E+00	1.749077	1.76E+00	1.755248	0.8	1.8
2.5	1.72E+00	1.76E+00	1.80E+00	1.74E+00	1.75E+00	1.76E+00	1.754087	0.8	1.8
4.4	1.72E+00	1.76E+00	1.793127	1.74E+00	1.75E+00	1.76E+00	1.752238	0.8	1.8
6.6	1.72E+00	1.757674	1.80E+00	1.737704051	1.75E+00	1.76E+00	1.753217	0.8	1.8
8.8	1.72E+00	1.76E+00	1.79E+00	1.74E+00	1.75E+00	1.76E+00	1.754277	0.8	1.8
11	1.72E+00	1.76E+00	1.79E+00	1.74E+00	1.747059	1.76E+00	1.753982	0.8	1.8
15	1.72E+00	1.76E+00	1.79E+00	1.74E+00	1.75E+00	1.76E+00	1.75316	0.8	1.8

<b>V3</b>		Biased			Unbiased			Control	Spec	
<b>Dose</b>										
<b>(krad(Si))</b>	<b>99LL</b>	<b>Mean</b>	<b>99UL</b>	<b>99LL</b>	<b>Mean</b>	<b>99UL</b>	<b>Mean</b>	<b>Min</b>	<b>Max</b>	
0	1.73E+00	1.75E+00	1.77E+00	1.73E+00	1.75E+00	1.771112	1.74E+00	0.8	1.8	
1.25	1.71E+00	1.75E+00	1.79E+00	1.73E+00	1.750529	1.77E+00	1.745132	0.8	1.8	
2.5	1.72E+00	1.75E+00	1.77E+00	1.73E+00	1.75E+00	1.77E+00	1.744332	0.8	1.8	
4.4	1.72E+00	1.75E+00	1.769692	1.73E+00	1.75E+00	1.77E+00	1.742613	0.8	1.8	
6.6	1.72E+00	1.74749	1.77E+00	1.72744137	1.75E+00	1.77E+00	1.743571	0.8	1.8	
8.8	1.72E+00	1.75E+00	1.77E+00	1.73E+00	1.75E+00	1.77E+00	1.744404	0.8	1.8	
11	1.72E+00	1.75E+00	1.77E+00	1.73E+00	1.74836	1.77E+00	1.744258	0.8	1.8	
15	1.72E+00	1.75E+00	1.77E+00	1.73E+00	1.75E+00	1.76E+00	1.743492	0.8	1.8	

<b>V4</b>		Biased			Unbiased			Control	Spec	
<b>Dose</b>										
<b>(krad(Si))</b>	<b>99LL</b>	<b>Mean</b>	<b>99UL</b>	<b>99LL</b>	<b>Mean</b>	<b>99UL</b>	<b>Mean</b>	<b>Min</b>	<b>Max</b>	
0	1.66E+00	1.67E+00	1.68E+00	1.67E+00	1.67E+00	1.673462	1.67E+00	0.8	1.8	
1.25	1.66E+00	1.67E+00	1.68E+00	1.66E+00	1.667582	1.67E+00	1.669893	0.8	1.8	
2.5	1.66E+00	1.67E+00	1.68E+00	1.66E+00	1.67E+00	1.67E+00	1.669068	0.8	1.8	
4.4	1.65E+00	1.67E+00	1.677044	1.66E+00	1.67E+00	1.67E+00	1.667191	0.8	1.8	
6.6	1.66E+00	1.666956	1.67E+00	1.66095877	1.67E+00	1.67E+00	1.668218	0.8	1.8	
8.8	1.65E+00	1.67E+00	1.68E+00	1.66E+00	1.67E+00	1.67E+00	1.669127	0.8	1.8	
11	1.66E+00	1.67E+00	1.67E+00	1.66E+00	1.665213	1.67E+00	1.669002	0.8	1.8	
15	1.66E+00	1.66E+00	1.67E+00	1.66E+00	1.66E+00	1.67E+00	1.6681	0.8	1.8	

B. Run Log

Beam Run	Time	E-tune (MeV)	Degraded	p energy at DUT surface	S/N	Run Time (s)	Mean Current (A)	Std Dev <A> (A)	Incr Dose for 64 MeV (rad/Si)	Acc Dose for 64 MeV (rad/Si)	Incr Fluence (p/cm <sup>2</sup> )	Acc Fluence (p/cm <sup>2</sup> )	Avg Dose Rate for 64 MeV (rad/Si/s)	Beam Profile	Ave Flux (p/cm <sup>2</sup> -s)	Faraday Cup Leakage (A)	FC Error +/-	SEM leakage (A)	SEM Error +/-	FC/SEM ratio	ratio error +/-	VF (V)	ave IF (A)	VCE (V)	Comments
Setup		11/7/2018	67.5	15 mil Ta	64																				
									Airgap 1.75 inches: unbiased board		S/N:	Bias condition													
									1.78 inches: biased board		2, 4, 6, 10	unbiased (all pins grounded)													
									NOT accounted for below		3, 7, 8, 9	biased (Vce = 5 V, IF = 2 mA)													
											1, 12	control group													
1	10:15:49	67.5	15 mil Ta	64	unbias	137.98	5.27E-10	5.08E-11	1.25E+03	1.25E+03	9.07E+09	9.07E+09	9.06E+00	0 - 0.5 cm	6.58E+07	1.90E-14 ± 3.810E-14		1.21E-11 ± 1.243E-13		1.84E+00 ± 8.4188E-03		0	0	0	Used built-in LET for Si which is only 8.334 MeV-cm <sup>2</sup> /g; corrected with SRIM 2013 value of 8.596
2	10:30:48	67.5	15 mil Ta	64	Biased	136.97	5.31E-10	5.17E-11	1.25E+03	1.25E+03	9.08E+09	9.09E+12	9.13E+00	0 - 0.5 cm	6.63E+07						3.8	0.0021	5	Accidentally entered LET in terms of mg rather than /g so dose was off by factor of 1000; corrected here	
3	11:11:13	67.5	15 mil Ta	64	unbias	138.24	5.26E-10	5.26E-11	1.25E+03	2.50E+03	9.08E+09	2.72E+10	9.05E+00	0 - 0.5 cm	6.57E+07						0	0	0		
4	11:33:39	67.5	15 mil Ta	64	Biased	139.36	5.24E-10	5.04E-11	1.26E+03	2.51E+03	9.12E+09	1.82E+10	9.02E+00	0 - 0.5 cm	6.55E+07						3.8	0.0021	5		
5	12:02:16	67.5	15 mil Ta	64	unbias	211.52	5.28E-10	4.17E-11	1.92E+03	4.42E+03	1.39E+10	3.21E+10	9.07E+00	0 - 0.5 cm	6.59E+07						0	0	0		
6	12:17:46	67.5	15 mil Ta	64	Biased	207.58	5.36E-10	4.26E-11	1.91E+03	4.42E+03	1.39E+10	3.20E+10	9.21E+00	0 - 0.5 cm	6.69E+07						3.8	0.0021	5		
7	12:39:59	67.5	15 mil Ta	64	unbias	245.72	5.22E-10	4.16E-11	2.21E+03	6.63E+03	1.60E+10	4.81E+10	8.98E+00	0 - 0.5 cm	6.52E+07						0	0	0		
8	13:02:21	67.5	15 mil Ta	64	Biased	245.83	5.23E-10	4.29E-11	2.21E+03	6.63E+03	1.61E+10	4.82E+10	8.99E+00	0 - 0.5 cm	6.53E+07						3.8	0.0021	5		
9	13:20:28	67.5	15 mil Ta	64	unbias	241.94	5.31E-10	4.06E-11	2.21E+03	8.83E+03	1.60E+10	6.42E+10	9.13E+00	0 - 0.5 cm	6.63E+07						0	0	0		
10	13:56:16	67.5	15 mil Ta	64	Biased	239.55	5.37E-10	4.13E-11	2.21E+03	8.84E+03	1.60E+10	6.42E+10	9.22E+00	0 - 0.5 cm	6.70E+07						3.8	0.0021	5		
11	14:16:39	67.5	15 mil Ta	64	unbias	240.73	5.32E-10	4.01E-11	2.20E+03	1.10E+04	1.60E+10	8.02E+10	9.14E+00	0 - 0.5 cm	6.64E+07						0	0	0		
12	14:49:31	67.5	15 mil Ta	64	Biased	240.61	5.33E-10	3.94E-11	2.20E+03	1.10E+04	1.60E+10	8.02E+10	9.16E+00	0 - 0.5 cm	6.65E+07						3.8	0.0021	5		
13	15:20:29	67.5	15 mil Ta	64	unbias	439.64	5.24E-10	3.74E-11	3.96E+03	1.50E+04	2.87E+10	1.09E+11	9.00E+00	0 - 0.5 cm	6.53E+07						0	0	0		
14	15:43:49	67.5	15 mil Ta	64	Biased	428.95	5.36E-10	3.04E-11	3.95E+03	1.50E+04	2.87E+10	1.09E+11	9.22E+00	0 - 0.5 cm	6.69E+07						3.8	0.0021	5		





