National Aeronautics and Space Administration

MT29F512G08AUCBBH8-6IT:B NAND Flash Memory
Total Ionizing Dose Test Report

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1. INTRODUCTION

The purpose of this test was to characterize the Micron 512 GB NAND (MT29F512G08AUCBBH8-6IT:B) flash memory parameter degradation for total dose response. In the test, the device was exposed to high dose rate (HDR) irradiations using gamma radiation. Device parameters such as leakage currents, quantity of upset bits and overall chip and die health were investigated.

2. DEVICES TESTED

2.1 Part Background

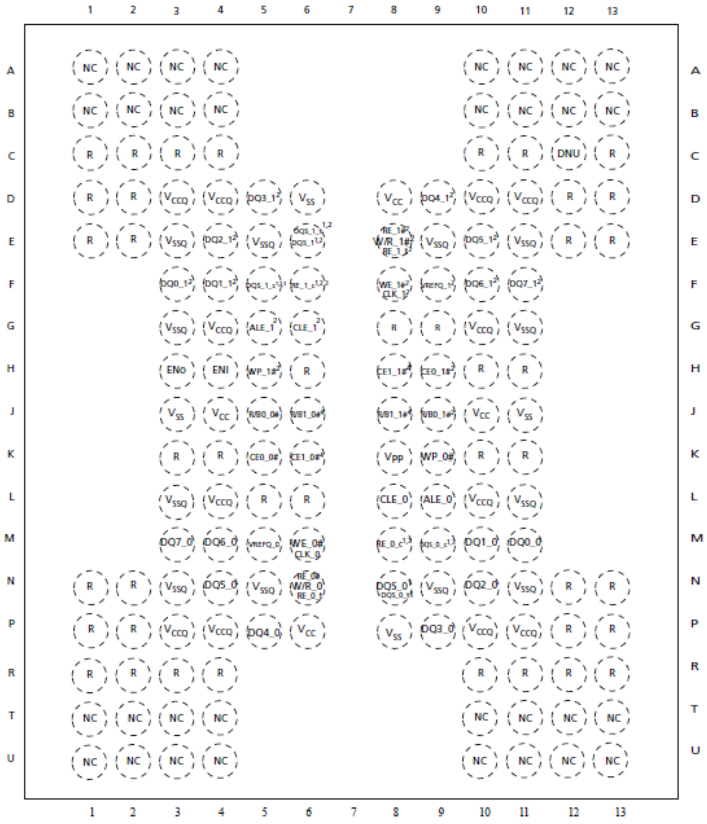
This Micron 512 GB NAND flash memory device has single-level cell (SLC) technology. It has a width of 8bits, contains 8 die with 4 chip enables. Its page size is 17,600 bytes, block size is 256 pages, and has 1048 blocks per plane with two planes. The package used for testing was the 152-ball LBGA.

2.2 Device Under Test (DUT) Information

Twelve parts of MT29F512G08AUCBBH8-6IT:B were tested for Total Ionizing Dose (TID). All specifications and descriptions are according to the datasheet (rev E 1/19/18). More information can be found in Table 1.

Table 1: Part Identification Information

Part Number	MT29F512G08AUCBBH8-6IT:B
Manufacturer	Micron
Lot Date Code	1722
Quantity Tested	12
Part Function	Flash Memory
Part Technology	CMOS
Package	152-ball LBGA



Notes:
1. N/A: This signal is tri-stated when the asynchronous interface is active.
2. These signals are available on dual, quad, and octal die packages. They are NC for other configurations.
3. These signals are available when differential signaling is enabled.
4. These signals are available on quad LUN four CE# or higher LUN stacked packages. They are NC for other configurations.

Figure 1: Picture of pinout of device

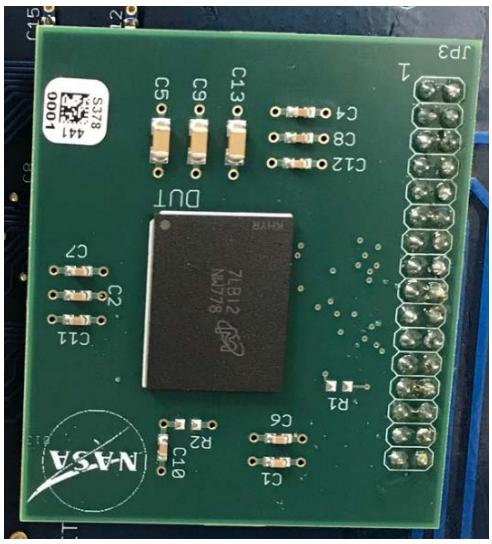


Figure 2: Picture of device on daughter card

3. TEST SETUP

Each DUT was mounted on its own daughter card. The Microcontroller Tester Board v2 has a Teensy 3.6 microcontroller on it. A LabVIEW program (Flash Tester in LabVIEW_v2) controlled the N6702A (ECN# M161852) power supply and sent commands to the Teensy microcontroller which in turn programmed, read, or erased parts of the flash memory device.

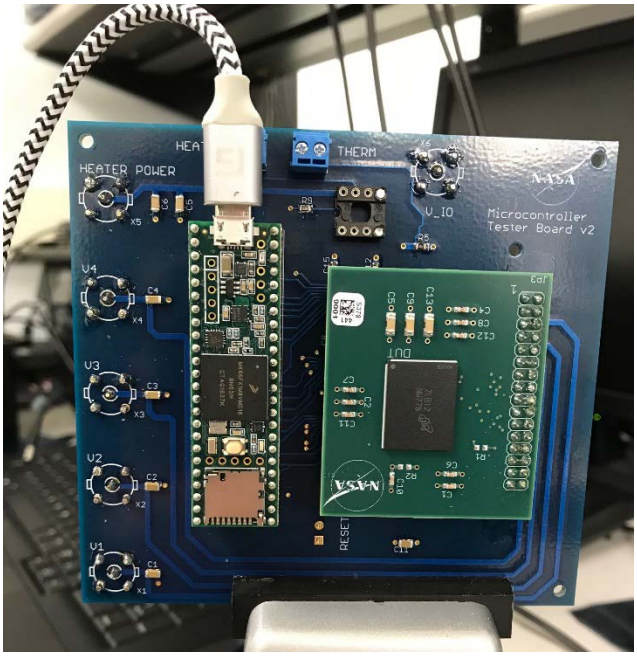


Figure 3: Picture of DUT on test board with Teensy 3.6 microcontroller

Table 2: Tester board connections

Pin	Signal	Voltage
V1	V_{CC}	3.3V
V2	V_{CCQ}	1.8V
V_{IO}	V_{IO}	1.8V

General test procedures were in accordance with MIL-STD-883, Method 1019, Condition D [1]. Parts were serialized randomly. Electrostatic Discharge (ESD) procedures were followed during test and transfer of the devices between irradiation chamber and characterization. Exposures were performed at ambient laboratory temperature.

4. TEST DESCRIPTION

4.1 Irradiation Conditions

Radiation testing was done by exposing the parts to gamma radiation at a high dose rate of 1182.4 rad/min. Twelve parts were tested, ten exposed to radiation and two as a control. Prior to the first radiation dose, all twelve parts were electrically tested and programmed. After each exposure level, the parts were tested again and returned to radiation within the

time limits defined by MIL-STD-883, Method 1019. Five parts were biased and five were unbiased during the irradiation steps. See Table 3 for more information. All devices under test (DUTs) were radiated over two days. Dose steps 5k, 10k, and 15k were exposed at a high dose rate of 1.182 krad/min. Dose step 30k was exposed at a low dose rate of 14.72 rad/min overnight. Finally, the last dose step of 50k was irradiated at the previous high dose rate.

Table 3: Device Grouping

Group	Qty	Bias	Dose Rate	Exposure Level Steps (krad(Si))
1	5	Biased	14.72 – 1182 rad(Si)/min	0, 5, 10, 15, 30, 50
2	5	Unbiased	14.72 – 1182 rad(Si)/min	0, 5, 10, 15, 30, 50

All parts were soldered to daughter cards which were placed on sockets to a copper bias board. During irradiation, DUTs 1 - 5 were powered to +3.3V_{cc} and +1.8V_{ccq}. Table 4 describes the exact pinout of a biased part.

Table 4: Biased DUT pinout

PIN#	SIGNAL	VOLTAGE
D8	V_{CC}	3.3V
J4	V_{CC}	3.3V
J10	V_{CC}	3.3V
P6	V_{CC}	3.3V
D3	V_{CCQ}	1.8V
D4	V_{CCQ}	1.8V
D10	V_{CCQ}	1.8V
D11	V_{CCQ}	1.8V
G4	V_{CCQ}	1.8V
G10	V_{CCQ}	1.8V
L4	V_{CCQ}	1.8V
L10	V_{CCQ}	1.8V
P3	V_{CCQ}	1.8V
P4	V_{CCQ}	1.8V
P10	V_{CCQ}	1.8V
P11	V_{CCQ}	1.8V
All remaining pins	various	GND

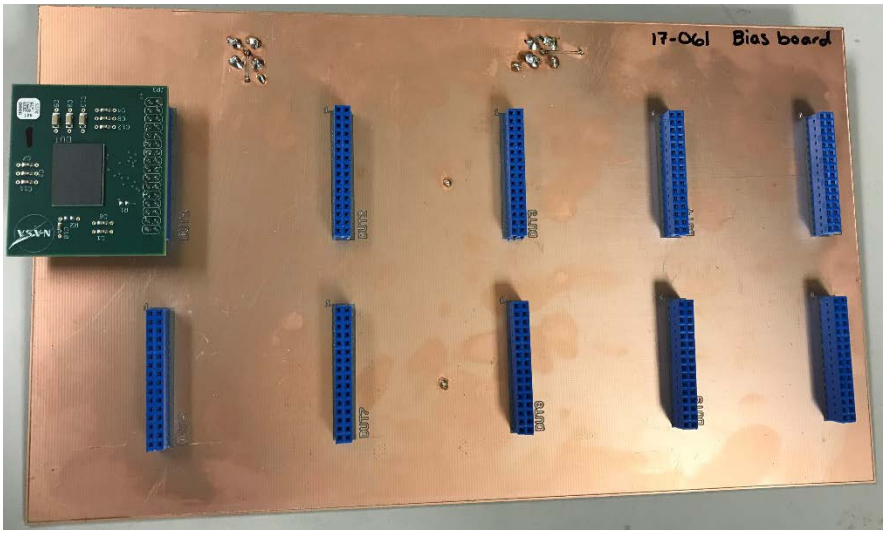


Figure 4: Bias board with one DUT mounted.

4.2 Electrical Tests

Specification thresholds were set in accordance with the MT29F512G08AUCBBH8-6IT:B datasheet [2].

All data from the DC electrical tests in Table 5 were logged in excel spreadsheet files using a N6702A power supply. Data for all parts were measured and logged.

Table 5: List of Electrical Tests Performed

Symbol	Parameter	MIN	TYP	MAX	Units	Test Conditions
I_{cc1}	Read Current		28	50	mA	
I_{cc2}	Program Current		37	50	mA	
I_{SB}	Standby Current		15	75	uA	CE# = V_{ccq} – 0.2V; WP# = 0V/V_{ccq}

5. Failure Criteria

The parameter limits are defined as those listed in the datasheet.

6. Source Requirements

The total dose source is in a room temperature air source gamma ray facility, which is compliant with MIL-STD-883, Method 1019. Dosimetry is NIST traceable.

7. RESULTS

Overall the DUTs were still functioning at 50k. The read-only section errors increased with dose while the read-write section errors remained stagnate over dose with the exception of the final 50k dose when those errors increased. The read-only errors were higher in the unbiased DUTs. Figure 5 shows the CE1 read-only digital memory errors over dose. Figure 6 shows the CE1 read-write digital errors.

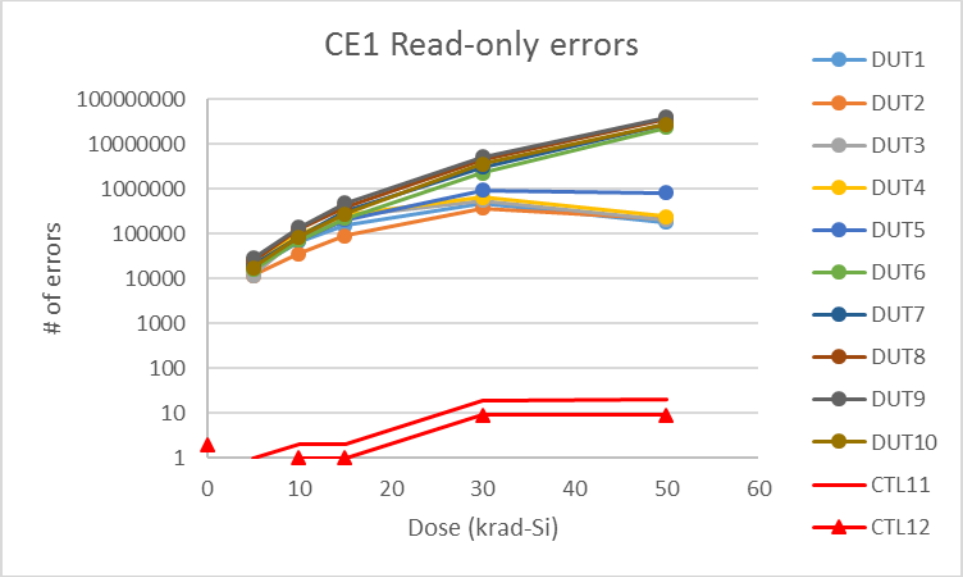


Figure 5. CE1 read-only errors on a log scale over dose.

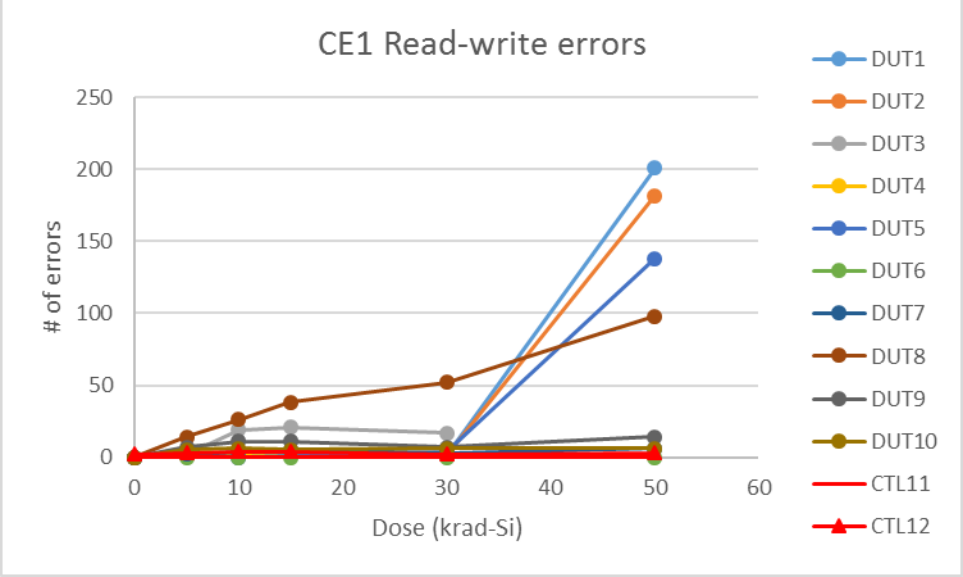


Figure 6. CE1 read-write errors over dose.

No current measurement went out of specification. Degradation was seen on the program and read currents at 15k and 30k respectively. (Shown in Figures 7 and 8.) Table 6 displays all the raw analog data. Table 7 displays all the digital memory errors data.

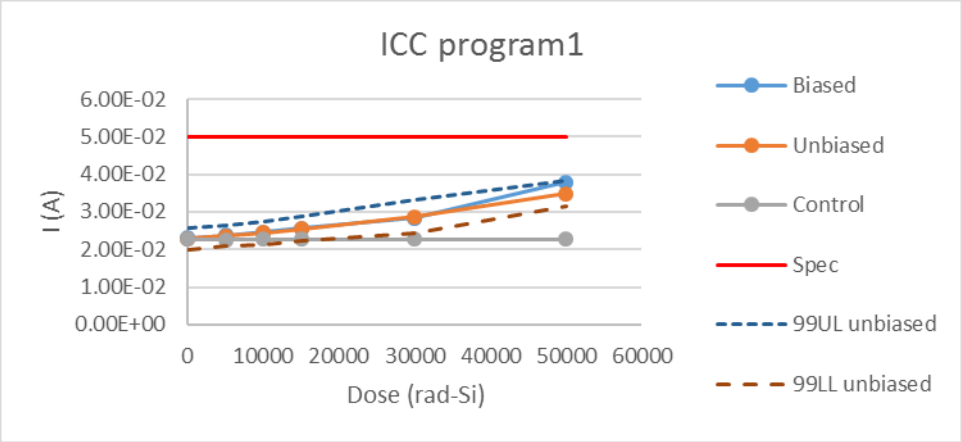


Figure 7. Program current of chip 1 over dose.

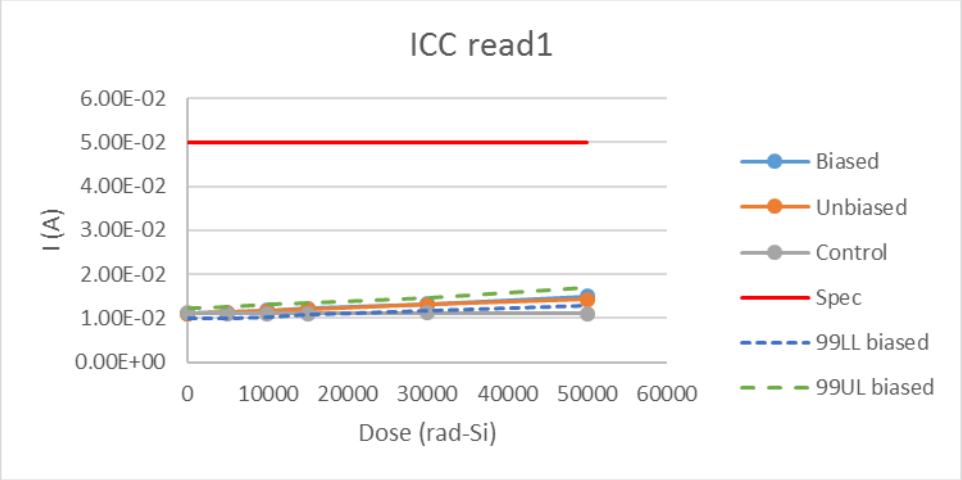


Figure 8. Read current of chip 1 over dose.

Table 6: Raw data

ICC program1	Biased			Unbiased			Control	Spec	
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**	
0	2.14E-02	2.30E-02	2.46E-02	2.00E-02	2.29E-02	2.58E-02	2.28E-02	5.00E-02	
5000	2.14E-02	2.37E-02	2.61E-02	2.10E-02	2.37E-02	2.63E-02	2.26E-02	5.00E-02	
10000	2.35E-02	2.47E-02	2.59E-02	2.13E-02	2.44E-02	2.75E-02	2.27E-02	5.00E-02	
15000	2.33E-02	2.57E-02	2.80E-02	2.22E-02	2.55E-02	2.87E-02	2.28E-02	5.00E-02	
30000	2.65E-02	2.84E-02	3.04E-02	2.42E-02	2.87E-02	3.32E-02	2.26E-02	5.00E-02	
50000	2.41E-02	3.79E-02	5.16E-02	3.13E-02	3.49E-02	3.84E-02	2.27E-02	5.00E-02	
ICC program2	Biased			Unbiased			Control	Spec	
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**	
0	2.14E-02	2.29E-02	2.44E-02	2.06E-02	2.33E-02	2.60E-02	2.34E-02	5.00E-02	
5000	2.21E-02	2.35E-02	2.49E-02	2.10E-02	2.38E-02	2.66E-02	2.35E-02	5.00E-02	
10000	2.27E-02	2.43E-02	2.60E-02	2.10E-02	2.46E-02	2.81E-02	2.33E-02	5.00E-02	
15000	2.31E-02	2.52E-02	2.74E-02	2.21E-02	2.58E-02	2.95E-02	2.33E-02	5.00E-02	
30000	2.77E-02	2.84E-02	2.92E-02	2.55E-02	2.86E-02	3.17E-02	2.33E-02	5.00E-02	
50000	3.18E-02	3.48E-02	3.78E-02	-6.72E-03	3.10E-02	6.87E-02	2.32E-02	5.00E-02	
ICC program3	Biased			Unbiased			Control	Spec	
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**	
0	2.12E-02	2.34E-02	2.57E-02	2.08E-02	2.34E-02	2.60E-02	2.29E-02	5.00E-02	
5000	2.18E-02	2.41E-02	2.64E-02	2.13E-02	2.38E-02	2.63E-02	2.29E-02	5.00E-02	
10000	2.22E-02	2.46E-02	2.71E-02	2.17E-02	2.46E-02	2.75E-02	2.27E-02	5.00E-02	
15000	2.31E-02	2.52E-02	2.82E-02	2.30E-02	2.55E-02	2.81E-02	2.28E-02	5.00E-02	
30000	2.55E-02	2.85E-02	3.14E-02	2.33E-02	2.78E-02	3.24E-02	2.33E-02	5.00E-02	
50000	2.87E-02	3.41E-02	3.95E-02	2.78E-02	3.31E-02	3.85E-02	2.30E-02	5.00E-02	
ICC program4	Biased			Unbiased			Control	Spec	
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**	
0	2.19E-02	2.31E-02	2.43E-02	2.09E-02	2.30E-02	2.50E-02	2.26E-02	5.00E-02	
5000	2.24E-02	2.37E-02	2.49E-02	2.07E-02	2.38E-02	2.68E-02	2.25E-02	5.00E-02	
10000	2.25E-02	2.44E-02	2.62E-02	2.25E-02	2.43E-02	2.60E-02	2.23E-02	5.00E-02	
15000	2.23E-02	2.56E-02	2.88E-02	2.10E-02	2.50E-02	2.90E-02	2.26E-02	5.00E-02	
30000	2.41E-02	2.81E-02	3.22E-02	2.37E-02	2.74E-02	3.11E-02	2.24E-02	5.00E-02	
50000	2.52E-02	3.34E-02	4.15E-02	2.72E-02	3.23E-02	3.75E-02	2.25E-02	5.00E-02	

ICC read1	Biased			Unbiased			Control	Spec
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**
0	9.90E-03	1.11E-02	1.23E-02	9.84E-03	1.10E-02	1.22E-02	1.12E-02	5.00E-02
5000	1.01E-02	1.14E-02	1.27E-02	9.81E-03	1.13E-02	1.28E-02	1.11E-02	5.00E-02
10000	1.03E-02	1.18E-02	1.33E-02	1.04E-02	1.17E-02	1.31E-02	1.11E-02	5.00E-02
15000	1.08E-02	1.22E-02	1.36E-02	1.05E-02	1.21E-02	1.37E-02	1.11E-02	5.00E-02
30000	1.17E-02	1.32E-02	1.47E-02	1.16E-02	1.31E-02	1.45E-02	1.12E-02	5.00E-02
50000	1.30E-02	1.49E-02	1.69E-02	1.34E-02	1.43E-02	1.52E-02	1.11E-02	5.00E-02
ICC read2	Biased			Unbiased			Control	Spec
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**
0	1.00E-02	1.09E-02	1.18E-02	9.65E-03	1.11E-02	1.25E-02	1.12E-02	5.00E-02
5000	1.04E-02	1.12E-02	1.21E-02	9.92E-03	1.14E-02	1.28E-02	1.12E-02	5.00E-02
10000	1.05E-02	1.16E-02	1.27E-02	1.00E-02	1.17E-02	1.33E-02	1.11E-02	5.00E-02
15000	1.08E-02	1.19E-02	1.31E-02	1.08E-02	1.21E-02	1.34E-02	1.12E-02	5.00E-02
30000	1.16E-02	1.29E-02	1.41E-02	1.15E-02	1.30E-02	1.45E-02	1.12E-02	5.00E-02
50000	1.35E-02	1.46E-02	1.56E-02	1.13E-02	1.39E-02	1.66E-02	1.13E-02	5.00E-02
ICC read3	Biased			Unbiased			Control	Spec
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**
0	1.03E-02	1.14E-02	1.25E-02	9.90E-03	1.12E-02	1.26E-02	1.11E-02	5.00E-02
5000	9.97E-03	1.16E-02	1.33E-02	1.01E-02	1.15E-02	1.28E-02	1.11E-02	5.00E-02
10000	1.03E-02	1.19E-02	1.36E-02	1.03E-02	1.18E-02	1.33E-02	1.11E-02	5.00E-02
15000	1.06E-02	1.23E-02	1.40E-02	1.05E-02	1.22E-02	1.38E-02	1.11E-02	5.00E-02
30000	1.16E-02	1.31E-02	1.47E-02	1.14E-02	1.30E-02	1.46E-02	1.11E-02	5.00E-02
50000	1.35E-02	1.47E-02	1.59E-02	1.26E-02	1.41E-02	1.56E-02	1.11E-02	5.00E-02
ICC read4	Biased			Unbiased			Control	Spec
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**
0	9.97E-03	1.14E-02	1.27E-02	9.36E-03	1.11E-02	1.28E-02	1.11E-02	5.00E-02
5000	9.75E-03	1.16E-02	1.34E-02	9.75E-03	1.13E-02	1.29E-02	1.12E-02	5.00E-02
10000	1.01E-02	1.19E-02	1.37E-02	9.97E-03	1.16E-02	1.33E-02	1.12E-02	5.00E-02
15000	1.01E-02	1.23E-02	1.44E-02	1.05E-02	1.20E-02	1.34E-02	1.11E-02	5.00E-02
30000	1.12E-02	1.31E-02	1.50E-02	1.09E-02	1.28E-02	1.47E-02	1.11E-02	5.00E-02
50000	1.32E-02	1.46E-02	1.60E-02	1.25E-02	1.40E-02	1.55E-02	1.11E-02	5.00E-02

Istby1		Biased			Unbiased		Control	Spec	
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**	
0	1.05E-03	1.44E-03	1.84E-03	1.03E-03	1.30E-03	1.57E-03	1.54E-03	7.50E-05	
5000	8.34E-04	1.31E-03	1.78E-03	7.95E-04	1.25E-03	1.70E-03	1.28E-03	7.50E-05	
10000	1.14E-03	1.27E-03	1.39E-03	1.06E-03	1.34E-03	1.63E-03	1.23E-03	7.50E-05	
15000	8.92E-04	1.30E-03	1.71E-03	1.05E-03	1.24E-03	1.43E-03	1.44E-03	7.50E-05	
30000	9.37E-04	1.30E-03	1.67E-03	9.19E-04	1.22E-03	1.53E-03	1.41E-03	7.50E-05	
50000	1.14E-03	1.34E-03	1.55E-03	7.21E-04	1.20E-03	1.68E-03	1.39E-03	7.50E-05	
Istby2		Biased			Unbiased		Control	Spec	
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**	
0	1.11E-03	1.43E-03	1.74E-03	9.75E-04	1.31E-03	1.65E-03	1.52E-03	7.50E-05	
5000	8.90E-04	1.27E-03	1.65E-03	9.32E-04	1.27E-03	1.61E-03	1.37E-03	7.50E-05	
10000	8.97E-04	1.26E-03	1.62E-03	8.62E-04	1.28E-03	1.70E-03	1.30E-03	7.50E-05	
15000	9.19E-04	1.28E-03	1.64E-03	1.02E-03	1.30E-03	1.59E-03	1.41E-03	7.50E-05	
30000	9.67E-04	1.33E-03	1.70E-03	9.83E-04	1.29E-03	1.60E-03	1.44E-03	7.50E-05	
50000	9.38E-04	1.31E-03	1.67E-03	4.65E-04	1.20E-03	1.93E-03	1.35E-03	7.50E-05	
Istby3		Biased			Unbiased		Control	Spec	
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**	
0	1.19E-03	1.43E-03	1.67E-03	7.89E-04	1.27E-03	1.76E-03	1.40E-03	7.50E-05	
5000	8.20E-04	1.23E-03	1.64E-03	1.05E-03	1.34E-03	1.63E-03	1.29E-03	7.50E-05	
10000	9.51E-04	1.26E-03	1.57E-03	1.09E-03	1.30E-03	1.51E-03	1.27E-03	7.50E-05	
15000	1.00E-03	1.29E-03	1.59E-03	8.36E-04	1.24E-03	1.65E-03	1.40E-03	7.50E-05	
30000	8.22E-04	1.30E-03	1.78E-03	1.18E-03	1.30E-03	1.42E-03	1.40E-03	7.50E-05	
50000	1.07E-03	1.32E-03	1.57E-03	8.53E-04	1.31E-03	1.77E-03	1.33E-03	7.50E-05	
Istby4		Biased			Unbiased		Control	Spec?	
Dose	**99LL**	**Mean**	**99UL**	**99LL**	**Mean**	**99UL**	**Mean**	**Max**	
0	1.15E-03	1.42E-03	1.69E-03	8.25E-04	1.34E-03	1.86E-03	1.45E-03	7.50E-05	
5000	6.91E-04	1.31E-03	1.94E-03	9.93E-04	1.28E-03	1.57E-03	1.34E-03	7.50E-05	
10000	1.07E-03	1.28E-03	1.48E-03	8.18E-04	1.27E-03	1.73E-03	1.20E-03	7.50E-05	
15000	1.06E-03	1.32E-03	1.58E-03	1.09E-03	1.28E-03	1.47E-03	1.38E-03	7.50E-05	
30000	1.08E-03	1.33E-03	1.58E-03	1.01E-03	1.26E-03	1.50E-03	1.41E-03	7.50E-05	
50000	8.66E-04	1.31E-03	1.75E-03	1.13E-03	1.36E-03	1.60E-03	1.37E-03	7.50E-05	

Table 7: Digital Memory raw data (outliers highlighted)

DUT	krads-Si	0	5		10		15		30		50	
			Read-only	RW	Read-only	RW	Read-only	RW	Read-only	RW	Read-only	RW
1	CE1	0	16403	3	67483	2	152472	3	473017	1	177183	201
	CE2	0	19863	10	70282	10	185642	13	1176668	23	1204018	20
	CE3	0	15016	2	53328	2	134039	0	763266	1	874607	2
	CE4	0	12744	0	44980	1	128087	1	755468	1	677030	129
2	CE1	0	11658	2	36095	2	90271	1	364614	1	219135	182
	CE2	0	20075	11	72430	13	188591	14	779895	13	396390	145
	CE3	0	18790	0	60011	1	157110	0	726747	1	823576	4
	CE4	0	19876	3	76558	4	190245	4	1066463	6	1165766	5
3	CE1	0	11658	2	85760	19	242285	21	551791	17	207071	36238
	CE2	0	20075	11	84495	9	220893	7	1403845	10	1146108	6
	CE3	0	18790	0	73161	2	191896	0	1140386	1	2028589	0
	CE4	0	19876	3	70980	3	225973	2	1261812	6	2145503	6
4	CE1	0	24908	4	97946	3	262677	3	640923	2	245284	174151
	CE2	0	15519	0	62703	0	167134	0	618119	1	454233	682
	CE3	0	17623	1	67424	2	177890	1	850207	2	562763	132
	CE4	0	13875	1	52411	0	138341	0	714207	0	476995	2
5	CE1	0	18487	1	71868	0	202291	1	938220	4	821313	138
	CE2	0	14959	2	58685	5	149130	5	869989	4	800955	6
	CE3	0	14870	0	54267	0	156180	0	622446	0	381269	115
	CE4	0	11065	1	45055	1	120552	1	550626	0	390780	2
6	CE1	0	15753	0	71695	0	219757	0	2240504	0	23399681	0
	CE2	0	21005	0	92728	1	296371	5	2822277	0	28296188	1
	CE3	0	16513	0	69548	2	193618	4	1723389	0	17501442	1
	CE4	0	15740	2	68336	1	203754	3	1726816	1	15983341	1
7	CE1	0	20594	2	87741	4	312612	5	3075571	3	28245369	6
	CE2	0	25556	22	125086	31	422031	35	4363163	53	37018249	63
	CE3	0	23954	0	107951	0	340212	0	3114451	0	27070521	1
	CE4	0	17598	1	78392	0	237415	1	2000303	1	19822301	0
8	CE1	0	25393	14	126916	26	396424	38	4337096	52	36810793	98
	CE2	0	31212	5	153428	3	485523	3	4631364	1	83886080	1.68E+08
	CE3	0	19603	7	87142	11	273620	7	2270591	11	22140622	13
	CE4	0	19746	3	92316	7	314826	9	2774420	8	25133560	11
9	CE1	0	28088	7	136024	11	482413	11	5111965	7	39972816	14
	CE2	0	26829	0	128009	0	401770	0	4219124	0	34361214	1
	CE3	0	24085	0	104320	0	335211	2	3190814	2	26019414	2
	CE4	0	25718	5	116429	7	376516	9	3232685	6	30244399	13
10	CE1	0	17316	5	83138	6	276713	5	3636086	6	27520908	6
	CE2	0	22195	0	109272	3	362872	2	3682846	3	32447870	1
	CE3	0	17775	2	80780	4	255302	2	2284611	8	20070743	8
	CE4	0	16432	0	77766	2	245523	1	2529791	0	22716158	1
Ctl11	CE1	0	1	0	2	0	2	0	19	0	20	0
	CE2	0	5	3	6	3	7	1	13	1	14	2
	CE3	0	0	0	0	0	0	1	1	0	2	0
	CE4	0	0	1	0	1	1	1	2	1	2	0
Ctl12	CE1	2	0	3	1	4	1	4	9	2	9	3
	CE2	2	3	3	3	1	4	2	16	2	19	3
	CE3	2	0	1	1	2	1	1	2	2	2	1
	CE4	2	1	0	1	0	1	0	6	2	6	0

8. CONCLUSIONS

9. REFERENCES

[1] Department of Defense “Test Method Standard Microcircuits,” MIL-STD-883 Test Method 1019.9 Ionizing radiation (total dose) test procedure, June 7, 2013, https://landandmaritimeapps.dla.mil/Downloads/MilSpec/Docs/MIL-STD-883/std883.pdf.

[2] Micron NAND Flash Memory MT29F64G08AB[C/E]BB, MT29F128G08AE[C/E]BB, MT29F256G08AK[C/E]BB, MT29F256G08AM[C/E]BB, MT29F512G08AU[C/E]BB, M84C_64_128_256_512Gb_Async_Sync_NAND.pdf Rev. E 1/19/18 datasheet.