

National Aeronautics and Space Administration



LM193 Dual Differential Comparator Total Ionizing Dose Test Report

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1. INTRODUCTION

The purpose of this test was to characterize the flight lot of Texas Instruments' LM193 (flight part number is 5962-9452601Q2A) for total dose response. This test served as the radiation lot acceptance test (RLAT) for the lot date code (LDC) tested. Low dose rate (LDR) irradiations were performed in this test so that the device susceptibility to enhanced low dose rate sensitivity (ELDRS) was determined.

2. DEVICES TESTED

2.1 Part Background

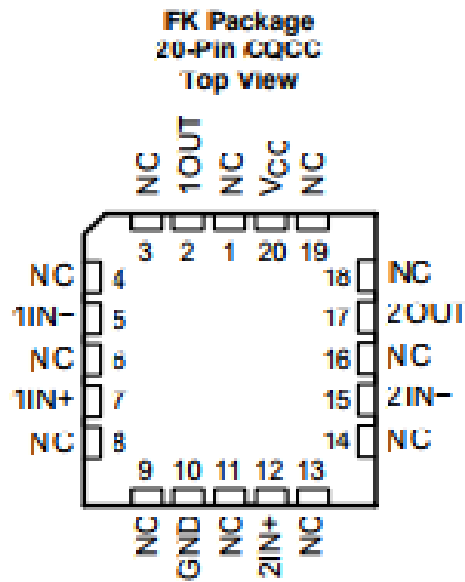
The LM193 is a dual differential comparator designed to operate from a single power supply over a wide range of voltages.

2.2 Device Under Test (DUT) Information

Seven parts from the flight lot of LM193 were tested for Total Ionizing Dose (TID). All specifications and descriptions are according to the datasheet (5962-94526 revJ). More information can be found in Table 1.

Table 1: Part Identification Information

Part Number	5962-9452601Q2A
Generic Part Number	LM193
Manufacturer	Texas Instruments
Lot Date Code	0624A
Quantity Tested	7
Part Function	Comparator
Part Technology	Bipolar
Package	FK 20-Pin CQCC



NC – NO internal connection

Figure 1: Pinout of LM139.

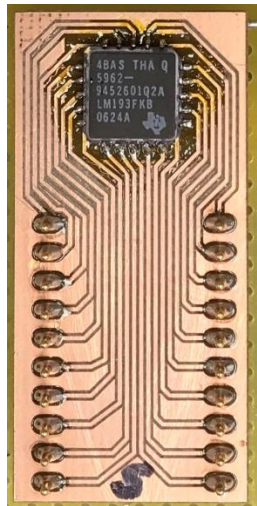


Figure 2: Picture of DUT on daughter card

3. TEST SETUP

LM193 parameters were measured with a Keithley 4200 Parametric Analyzer.

General test procedures were in accordance with MIL-STD-883, Method 1019, Condition D. Parts were serialized randomly. 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 dose rate of 10 mrad(Si)/s. Seven parts were tested, six exposed to radiation and one as a control. Prior to the first radiation dose, all seven 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. All six parts were biased during the irradiation steps. See Table 2 for more information.

Table 2: Device Grouping

Qty	Bias	Dose Rate	Exposure Level Steps (krad(Si))
6	Biased	10 mrad(Si)/s	0, 2.5, 5, 7.5, 10, 12, 15, 20

The biased parts on their daughter cards were placed in a DIP socket on a wire wrapped board. During irradiation, DUTs were powered to +30V. Table 3 describes the exact pinout of a biased part.

Table 3: Biased DUT pinout

PIN#	SIGNAL	VOLTAGE
1	NC	-
2	1OUT	-
3	NC	-
4	NC	-
5	1IN-	GND
6	NC	-
7	1IN+	+5V
8	NC	-
9	NC	-
10	GND	GND
11	NC	-
12	2IN+	+5V
13	NC	-
14	NC	-

15	2IN-	GND
16	NC	-
17	2OUT	-
18	NC	-
19	NC	-
20	V _{cc}	+30V

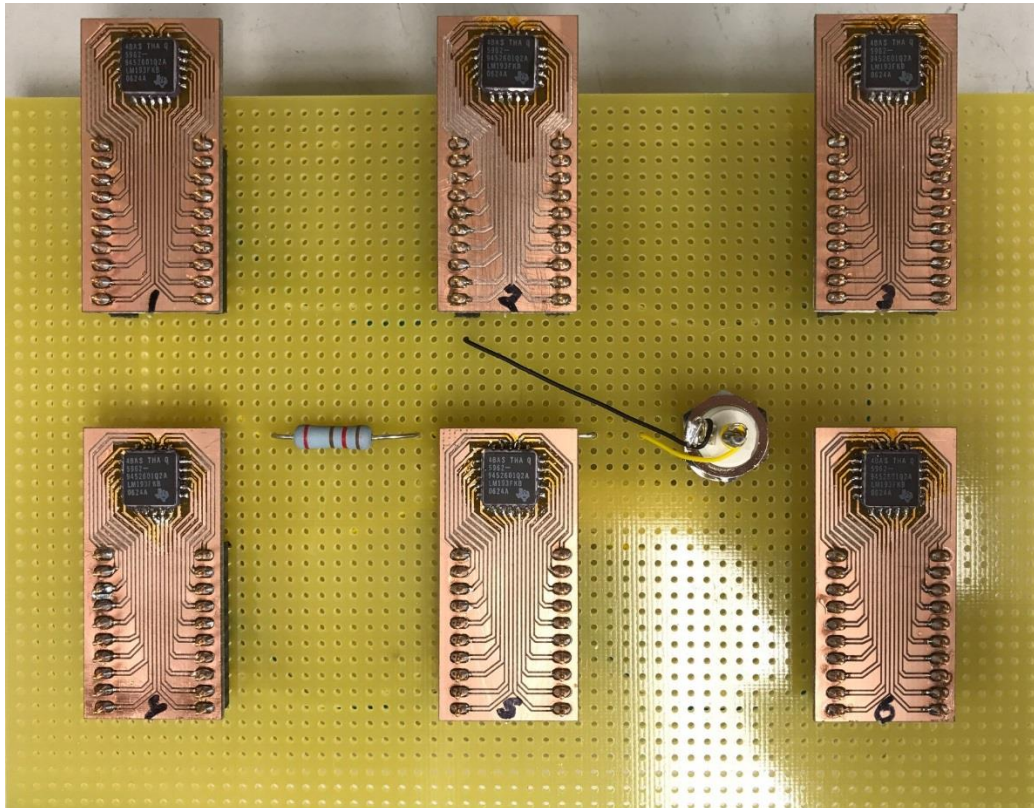


Figure 3: LM193 bias board

4.2 Electrical Tests

Specification thresholds were set in accordance with the LM193 datasheet.

All data from the DC electrical tests in Table 4 were logged in excel spreadsheet files using a Keithley 4200 Parametric Analyzer. Data for all parts were measured and logged.

Table 4: List of Electrical Tests Performed

Parameter	Symbol	MIN	TYP	MAX	Unit	Test Condition
Input Offset Voltage	V_{IO}			5	mV	$V_{CC} = 5 \text{ V to } 30 \text{ V}$, $V_{IC} = V_{IC \text{ min}}$, $V_{OUT} = 1.4 \text{ V}$
Input Bias Current	I_{IB}			-100	nA	$V_{OUT} = 1.4 \text{ V}$
Input Offset Current	I_{IO}			25	nA	$V_{OUT} = 1.4 \text{ V}$
Supply Current	I_{CC}			1	mA	$V_{CC} = 5 \text{ V}$, $R_L = \text{infinity}$, $T_A = +25\text{C}$
Low Level Output Voltage	V_{OL}			400	mV	$I_{OL} = 4 \text{ mA}$, $V_{ID} = -1 \text{ V}$
Low Level Output Current	I_{OL}	6			mA	$V_{OL} = 1.5 \text{ V}$, $V_{ID} = -1 \text{ V}$

5. FAILURE CRITERIA

The parameter limits are defined as those listed in the LM193 datasheet. All parameters remained within specification. Input bias current showed degradation but remained with specification up to 20 krads.

6. SOURCE REQUIREMENTS

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

7. RESULTS

Only input bias current showed degradation close to its maximum specification. Supply current stayed within specification and showed no degradation over dose. All other measured parameters stayed within specification or degraded insignificantly.

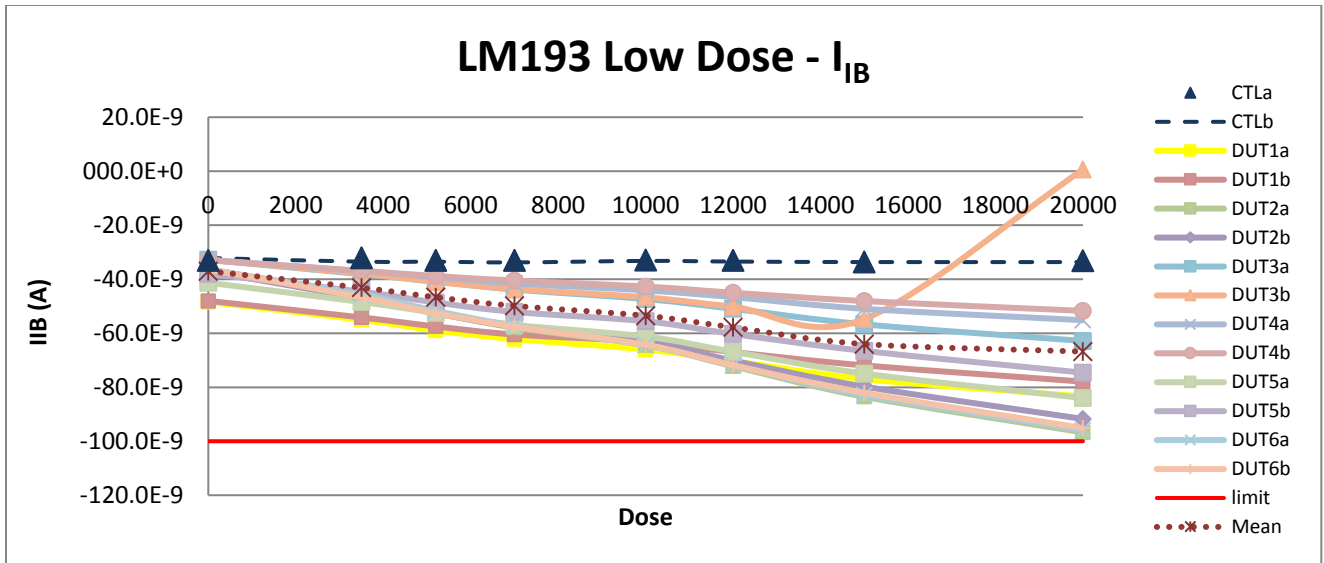


Figure 4. Input Bias Current vs. Dose.

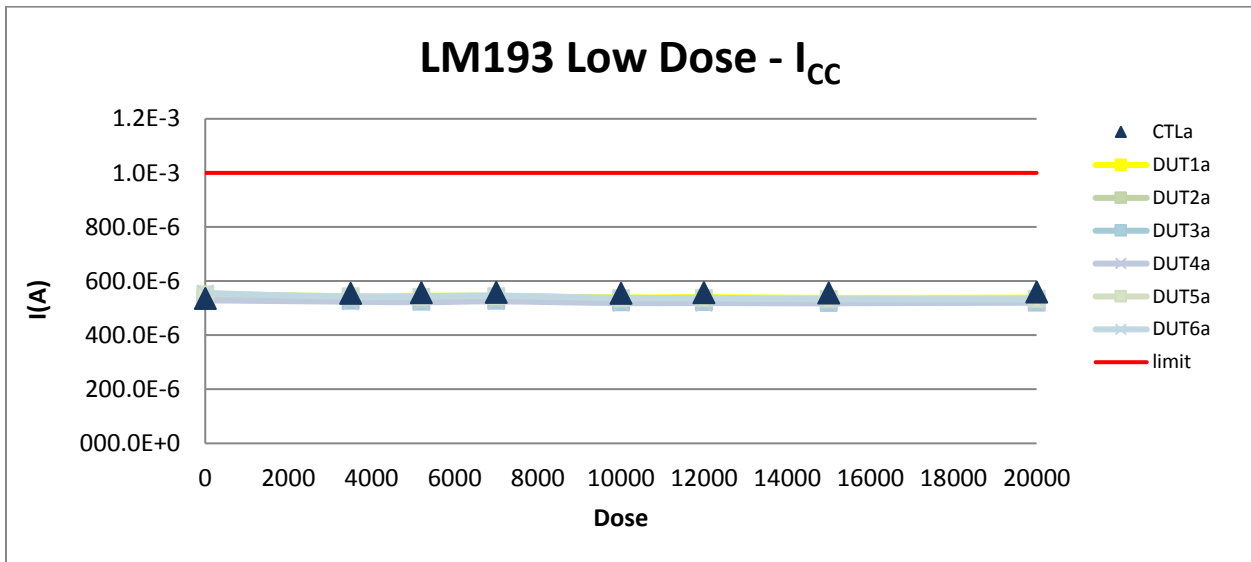


Figure 5. Supply Current vs. Dose

Table 5: Raw data

LM193 Low Dose				days	4.05	1.97	2.08	3.47	2.31	3.47	5.79	
10mrad/sec				hr	97.22	47.22	50.00	83.33	55.56	83.33	138.89	
dose rate		0.6 (rad/min)		min	5833.33	2833.33	3000.00	5000.00	3333.33	5000.00	8333.33	
		36 rad/hr			8/16/17 2:40 PM	8/21/17 2:40 PM	8/23/17 1:53 PM	8/25/17 3:53 PM	8/29/17 2:40 PM	9/1/17 2:40 PM	9/5/17 2:40 PM	9/11/17 9:33 AM
DUT	side	Total Dose (rad)			0	3500	5200	7000	10000	12000	15000	20000
Control	a	V _{IO}	V		943.0E-6	-2.1E-3	27.9000E-6	27.2000E-6	14.9000E-6	13.9000E-6	1.0200E-3	26.1000E-6
	a	I _{IB}	A		-33.0E-9	-32.1E-9	-32.9622E-9	-33.0281E-9	-32.8911E-9	-32.9920E-9	-33.5508E-9	-33.1043E-9
	a	I _{IO}	A		48.4E-12	-1.2E-9	99.2237E-12	73.0722E-12	66.1906E-12	157.7654E-12	1.3638E-9	66.7448E-12
	a	I _{CC}	A		536.5E-6	555.7E-6	557.5264E-6	558.6948E-6	555.8461E-6	557.9108E-6	556.1997E-6	559.9806E-6
	a	V _{OL}	V		125.8077E-3	125.3434E-3	125.0806E-3	124.9556E-3	125.5882E-3	125.1059E-3		124.7244E-3
	a	I _{OL}	A		19.9989E-3	19.9986E-3	19.9988E-3	19.9989E-3	19.9988E-3	19.9988E-3	19.9989E-3	19.9993E-3
	b	V _{IO}	V		942.9E-6	1.9E-3	-976.0000E-6	-975.0000E-6	-971.0000E-6	-962.0000E-6	-968.0000E-6	-978.0000E-6
	b	I _{IB}	A		-32.1E-9	-33.5E-9	-33.5119E-9	-33.7721E-9	-33.2163E-9	-33.4609E-9	-33.6434E-9	-33.6492E-9
	b	I _{IO}	A		-339.7E-12	-322.4E-12	-225.9348E-12	-256.5841E-12	-186.2510E-12	-119.7265E-12	-84.8814E-12	-266.0663E-12
	b	V _{OL}	V		121.5383E-3	121.3636E-3	121.1378E-3	124.9556E-3	121.9089E-3	121.2153E-3	120.6915E-3	120.7735E-3
	b	I _{OL}	A		19.9988E-3	19.9987E-3	19.9988E-3	19.9991E-3	19.9987E-3		19.9989E-3	19.9994E-3
	1 a	V _{IO}	V		944.0E-6	942.1E-6	-974.0000E-6	-974.0000E-6	-955.0000E-6	-973.0000E-6	1.0300E-3	-979.0000E-6
	a	I _{IB}	A		-48.4E-9	-55.0E-9	-58.9927E-9	-62.1383E-9	-66.0318E-9	-70.2914E-9	-76.9664E-9	-83.4006E-9
	a	I _{IO}	A		-4.4E-9	-5.8E-9	-6.7096E-9	-7.5214E-9	-7.5566E-9	-9.0614E-9	-8.1474E-9	-12.7818E-9
	a	I _{CC}	A		549.1395E-6	544.1E-6	545.8824E-6	544.9226E-6	539.2973E-6	540.8042E-6	537.8783E-6	539.0103E-6
	a	V _{OL}	V		121.9173E-3	125.3434E-3	123.5772E-3	123.4606E-3	124.7691E-3	125.1059E-3	124.3956E-3	124.8631E-3
	a	I _{OL}	A		19.9987E-3	19.9985E-3	19.9987E-3	19.9989E-3	19.9988E-3	19.9989E-3	19.9990E-3	19.9993E-3
	b	V _{IO}	V		-62.0E-6	939.1E-6	28.6000E-6	30.4000E-6	33.1000E-6	42.3000E-6	20.7000E-6	26.7000E-6
	b	I _{IB}	A		-48.0E-9	-54.1E-9	-57.4811E-9	-60.4671E-9	-63.2320E-9	-66.9600E-9	-71.9126E-9	-77.9268E-9
	b	I _{IO}	A		-410.4E-12	-810.5E-12	-1.1245E-9	-1.1180E-9	-168.2992E-12	-987.6686E-12	-1.6047E-9	-2.3623E-9
	b	V _{OL}	V		117.9382E-3	120.3531E-3	119.6323E-3	119.7168E-3	120.9330E-3	121.2153E-3	120.0581E-3	120.7735E-3
	b	I _{OL}	A		19.9986E-3	19.9986E-3	19.9988E-3	19.9991E-3	19.9986E-3	19.9989E-3	19.9989E-3	19.9993E-3
	2 a	V _{IO}	V		942.8E-6	941.0E-6	-973.0000E-6	-975.0000E-6	-954.0000E-6	-970.0000E-6	29.7000E-6	-979.0000E-6
	a	I _{IB}	A		-36.2E-9	-46.8E-9	-52.4714E-9	-57.9387E-9	-64.4502E-9	-72.2289E-9	-83.5162E-9	-96.7213E-9
	a	I _{IO}	A		292.3E-12	333.0E-12	510.1413E-12	468.6207E-12	729.8908E-12	659.9663E-12	3.5525E-9	695.8061E-12
	a	I _{CC}	A		552.0E-6	541.3E-6	538.5928E-6	538.6901E-6	533.0488E-6	532.3450E-6	527.7842E-6	529.7202E-6
	a	V _{OL}	V		129.3755E-3	131.7411E-3	18.6157E-3	132.3741E-3	133.7490E-3	134.1908E-3	134.2659E-3	135.3765E-3
	a	I _{OL}	A		19.6056E-3	19.9985E-3	18.6157E-3	18.3575E-3	17.9305E-3	17.5640E-3	19.9990E-3	19.9993E-3
	b	V _{IO}	V		3.9E-3	3.9E-3	-3.9600E-3	-3.9600E-3	-3.9500E-3	-3.9400E-3	-3.9600E-3	-3.9600E-3
	b	I _{IB}	A		-37.1E-9	-47.1E-9	-52.6391E-9	-57.5473E-9	-63.0111E-9	-70.1513E-9	-79.7611E-9	-91.7407E-9
	b	I _{IO}	A		-485.6E-12	-604.2E-12	-533.4435E-12	-654.3743E-12	1.1073E-9	-108.3720E-12	-877.9395E-12	-1.6943E-9
	b	V _{OL}	V		117.9382E-3	125.7957E-3	126.2301E-3	126.8838E-3	128.2143E-3	128.4467E-3	119.9966E-3	130.3219E-3
	b	I _{OL}	A		19.4762E-3	18.8136E-3	19.9988E-3	18.2287E-3	17.8141E-3	19.9989E-3	19.9989E-3	19.9993E-3
	3 a	V _{IO}	V		-63.2E-6	941.5E-6	-976.0000E-6	2.0400E-3	-952.0000E-6	2.0500E-3	1.0400E-3	-980.0000E-6
	a	I _{IB}	A		-32.8E-9	-38.1E-9	-40.8672E-9	-43.8331E-9	-47.3313E-9	-50.9384E-9	-56.7125E-9	-62.8712E-9
	a	I _{IO}	A		143.9E-12	-325.8E-12	-545.4268E-12	-550.2443E-12	-548.8552E-12	-786.4607E-12	725.6737E-12	-1.8436E-9
	a	I _{CC}	A		535.4E-6	527.7E-6	524.5068E-6	528.7175E-6	521.7365E-6	522.8546E-6	519.7344E-6	521.1211E-6
	a	V _{OL}	V		116.2478E-3	131.7411E-3	118.6999E-3	118.0432E-3	133.7490E-3	119.6763E-3	134.2659E-3	19.9993E-3
	a	I _{OL}	A		19.9986E-3	19.9985E-3	19.9986E-3	20.0E-3	19.9991E-3	17.5640E-3	19.9989E-3	-2.9500E-3
	b	V _{IO}	V		3.9E-3	2.9E-3	-2.9500E-3	-2.9500E-3	-2.9500E-3	-2.9400E-3	-2.9600E-3	-60.9135E-9
	b	I _{IB}	A		-32.8E-9	-37.9E-9	-41.0128E-9	-43.6262E-9	-46.6987E-9	-50.1564E-9	-54.7203E-9	611.8270E-12
	b	I _{IO}	A		-314.8E-12	-124.1E-12	109.1891E-12	144.2793E-12	1.2908E-9	538.0691E-12	501.3732E-12	
	b	V _{OL}	V		123.6417E-3	115.7168E-3	115.6551E-3	126.8838E-3	128.2143E-3	118.1764E-3	116.6373E-3	117.5918E-3
	b	I _{OL}	A		19.9988E-3	19.9986E-3	19.9986E-3	19.9990E-3	19.9986E-3	19.9989E-3	19.9989E-3	19.9993E-3

4 a	V _{IO}	V	900.0E-6	940.2E-6	-975.0000E-6	-972.0000E-6	-953.0000E-6	-966.0000E-6	31.2000E-6	-978.0000E-6
a	I _{IB}	A	-32.8E-9	-37.1E-9	-39.2222E-9	-41.5697E-9	-44.1322E-9	-46.6281E-9	-50.9649E-9	-55.1701E-9
a	I _{IO}	A	-345.8E-12	-997.1E-12	-1.3468E-9	-1.5811E-9	-1.7657E-9	-2.4115E-9	-1.5747E-9	-4.1371E-9
a	I _{CC}	A	528.6E-6	523.7E-6	521.6314E-6	524.8783E-6	518.5750E-6	518.8601E-6	517.8390E-6	520.9708E-6
a	V _{OL}	V	114.3356E-3	115.4048E-3	115.5777E-3	115.2945E-3	116.3171E-3	116.3356E-3	115.7402E-3	116.1115E-3
a	I _{OL}	A	19.9986E-3	19.9985E-3	19.9986E-3	19.9988E-3	19.9991E-3	17.5640E-3	19.9989E-3	19.9993E-3
b	V _{IO}	V	-2.1E-3	-2.1E-3	2.0400E-3	2.0400E-3	2.0400E-3	2.0500E-3	2.0300E-3	2.0400E-3
b	I _{IB}	A	-33.0E-9	-36.9E-9	-38.8114E-9	-40.5037E-9	-42.7002E-9	-45.0041E-9	-48.0868E-9	-51.7032E-9
b	I _{IO}	A	123.5E-12	-34.6E-12	-79.4316E-12	-144.4036E-12	548.0061E-12	-16.4242E-12	-404.1816E-12	-1.1065E-9
b	V _{OL}	V	111.8949E-3	113.7290E-3	113.0532E-3	113.1968E-3	114.1061E-3	113.8224E-3	113.5202E-3	114.2236E-3
b	I _{OL}	A	19.9987E-3	19.9985E-3	19.9987E-3	19.9989E-3	19.9985E-3		19.9987E-3	19.9993E-3
5 a	V _{IO}	V	940.6E-6	1.9E-3	-975.0000E-6	-974.0000E-6	-952.0000E-6	-965.0000E-6	33.5000E-6	-979.0000E-6
a	I _{IB}	A	-41.3E-9	-48.4E-9	-52.4956E-9	-56.8775E-9	-61.2294E-9	-66.8592E-9	-74.9380E-9	-83.9968E-9
a	I _{IO}	A	-8.3E-9	-8.0E-9	-8.3903E-9	-8.8530E-9	-8.5337E-9	-9.4141E-9	-7.9079E-9	-11.3091E-9
a	I _{CC}	A	551.7E-6	544.3E-6	542.3566E-6	545.2546E-6	537.4331E-6	538.3007E-6	534.7279E-6	535.8258E-6
a	V _{OL}	V	114.3356E-3	130.1239E-3	130.5714E-3	129.6390E-3	131.2689E-3	116.3356E-3	130.8388E-3	131.4216E-3
a	I _{OL}	A	19.9988E-3	19.6400E-3	19.4747E-3	19.9988E-3	19.1172E-3	18.9638E-3	19.9989E-3	19.9993E-3
b	V _{IO}	V	940.3E-6	936.2E-6	-974.0000E-6	-974.0000E-6	-973.0000E-6	-979.0000E-6	-983.0000E-6	-975.0000E-6
b	I _{IB}	A	-38.0E-9	-44.6E-9	-48.6070E-9	-52.1197E-9	-55.5743E-9	-60.2816E-9	-66.5572E-9	-74.6027E-9
b	I _{IO}	A	31.8E-12	-1.0E-9	-1.5075E-9	-1.9198E-9	-1.3542E-9	-2.8844E-9	-4.0421E-9	-5.8316E-9
b	V _{OL}	V	111.8949E-3	124.4595E-3	124.2722E-3	113.1968E-3	114.1061E-3	125.5937E-3	125.4209E-3	126.2996E-3
b	I _{OL}	A	19.9850E-3	19.5835E-3	19.4364E-3	19.2774E-3	19.0436E-3	19.9989E-3	19.9987E-3	19.9993E-3
6 a	V _{IO}	V	941.1E-6	1.9E-3	-1.9800E-3	-1.9800E-3	-1.9800E-3	-1.9700E-3	-971.0000E-6	-1.9800E-3
a	I _{IB}	A	-36.4E-9	-45.7E-9	-51.6864E-9	-57.2686E-9	-64.4483E-9	-71.8626E-9	-82.8786E-9	-95.9186E-9
a	I _{IO}	A	422.1E-12	-333.6E-12	-566.3487E-12	-700.2114E-12	-880.2559E-12	-1.3827E-9	642.4159E-12	-2.8623E-9
a	I _{CC}	A	556.0E-6	540.7E-6	543.7136E-6	546.4944E-6	537.3299E-6	535.8123E-6	532.5473E-6	531.8261E-6
a	V _{OL}	V	129.0406E-3	131.6697E-3	131.5879E-3	131.4527E-3	133.6139E-3	133.8300E-3	133.7793E-3	135.1192E-3
a	I _{OL}	A	19.9021E-3	19.2359E-3	19.4747E-3	18.6981E-3	18.2063E-3	18.9638E-3	19.9989E-3	19.9993E-3
b	V _{IO}	V	941.1E-6	942.2E-6	-975.0000E-6	-973.0000E-6	-972.0000E-6	-978.0000E-6	-983.0000E-6	-977.0000E-6
b	I _{IB}	A	-36.4E-9	-46.7E-9	-52.5407E-9	-57.6009E-9	-64.2805E-9	-71.8304E-9	-82.0457E-9	-95.1186E-9
b	I _{IO}	A	422.1E-12	201.3E-12	144.9827E-12	155.7368E-12	1.8721E-9	557.6055E-12	-461.3128E-12	-1.0410E-9
b	V _{OL}	V	122.6951E-3	124.4595E-3	125.0604E-3	126.3449E-3	127.4393E-3	127.8030E-3	127.8669E-3	129.2961E-3
b	I _{OL}	A	19.9989E-3	19.3290E-3	19.4364E-3	18.7811E-3	19.0436E-3	19.9989E-3	19.9987E-3	19.9993E-3

8. CONCLUSIONS

Based on these results, 5962-9452601Q2A appears to be TID tolerant up to 20 krad.

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] 5962-94526 revJ datasheet, <https://landandmaritimeapps.dla.mil/Downloads/MilSpec/Smd/94526.pdf>