



U309 N-Channel Silicon Junction Field Effect Transistor Total Ionizing Dose Characterization Report

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1. Purpose

The purpose of this testing was to characterize the InterFET Corporation U309 for total dose response. This test shall serve as the radiation lot acceptance test (RLAT) for the lot date code (LDC) tested. The U309 is a discrete Junction Field Effect Transistor (JFET). High dose rate (HDR) irradiations were performed in this test so that the device susceptibility to Total Ionizing Dose (TID) could be determined.

2. Test Samples

Sixteen (16) parts from the flight lot of U309s were provided to Code 561 for TID testing. Two of the sixteen were used as controls. More information can be found in Table 1.

Table 1: Part Identification Information

Qty	Part Number	LDC	Package	REAG ID #
16	U309	1526	TO - 52	19-009

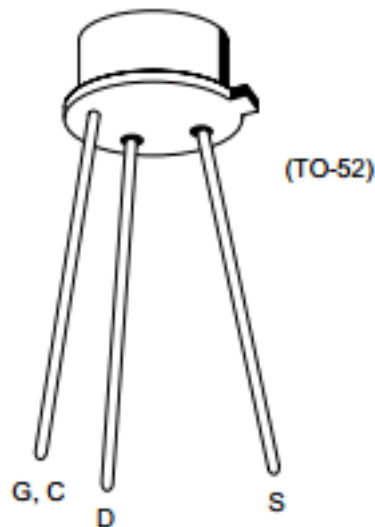


Figure 1: Pin out for U309 N-Channel JFET.

3. General

Radiation testing was done by exposing the parts to gamma radiation at a dose rate of 350 rad(Si)/min. 16 parts were tested – 14 exposed to radiation and the two remaining were unirradiated and used as controls. Prior to the first radiation dose, all parts were electrically tested using Keithly 2600 series sourcemeters, for $V_{GS(OFF)}$, I_{GSS} , and I_{DSS} . After each exposure level, the parts (including the controls) were tested again for $V_{GS(OFF)}$, I_{GSS} , and I_{DSS} . The parts were subjected to multiple levels of total dose and step level tested as shown in Table 2.

Table 2: Device Grouping and Step-Stress Instructions

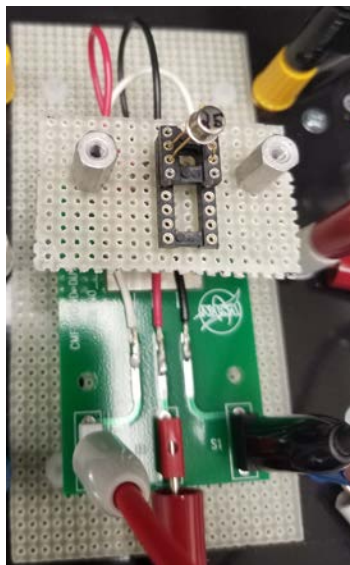
Group	Qty	Bias	Sample #	Dose Rate	Test Levels (krad(Si))
1	7	Biased	1	HDR 350 rad(Si)/min	0, 1, 2, 4, 6, 9, 12, 15, 25, 50
2	7	Unbiased	1	HDR 350 rad(Si)/min	0, 1, 2, 4, 6, 9, 12, 15, 25, 50

4. Electrical Tests

Electrical tests were performed in accordance with U309 datasheet. All test conditions listed for the following parameters were tested:

Table 3: List of Parameters to be measured

Test	Symbol	Conditions $T_A = +25^\circ\text{C}$	Specifications	
			Min	Max
Gate Reverse Current	I_{GSS}	$V_{GS} = -15\text{ V}, V_{DS} = 0\text{ V}$		-150 pA
Gate Source Cutoff Voltage	$V_{GS(OFF)}$	$V_{DS} = 10\text{ V}, I_D = 1\text{ nA}$	-1 V	-4 V
Drain Saturation Current	I_{DSS}	$V_{DS} = 10\text{ V}, V_{GS} = 0\text{ V}$	12 mA	30 mA

**Figure 2: Picture of electrical test board**

5. Failure Criteria

The parameter limits were defined as those listed in U309 Datasheet. Accurate parameter measurements were maintained beyond the specified limits when parameter drift was observed. When functional failure was observed, that result was noted in place of the parameter measurements.

6. Source Requirements

The total dose source was the GSFC ^{60}Co irradiator in the Radiation Effects Facility, which is compliant with MIL-STD-883, Method 1019. Dosimetry is NIST traceable.

7. Bias Conditions and Fixtures

The unbiased parts had all leads grounded during irradiation, while the biased part configuration was connected in the following way:

Table 4: Applied Voltages for Biased Irradiations

Pin Name	Pin Number	Connection
Source	S	-10 V ($V_{ds} = 10V$)
Drain	D	1 k Ω resistor to GND (limits I_{dss} to 10mA)
Gate & Case	G, C	1 k Ω resistor to GND (or tied to GND)

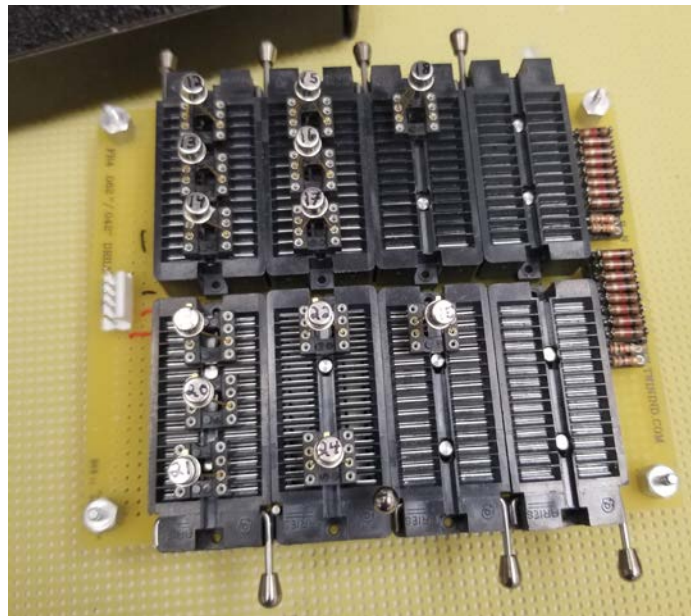


Figure 3: Picture of DUTs on bias board

8. Procedure

General test procedures were in accordance with MIL-STD-883, Method 1019.9, Condition C. Parts were serialized, with controls marked prominently to distinguish them from test samples. Exposures were performed at ambient laboratory temperature. Approximate cumulative test levels are provided by the values in Table 2.

All data from the evaluation of the parameters in Table 3 was logged in Microsoft Excel. Data for all parts was measured and logged. Along with the data logging, detailed schematics for the test parameter extraction circuits were also recorded.

9. Results

Provided in this section are the schematics used for making each measurement, the raw data collected, and graphic representation of the data. In this section, 10 and 11 are the serial numbers assigned to the control parts, while serial numbers 12 through 18 are the parts that were irradiated with all pins grounded and serial numbers 19-25 are the parts that were biased during irradiation.

The figures only show the 99/90 confidence levels for the biased devices, because this group showed the greatest degradation as a function of total ionizing dose. However, the values for the biased group were also calculated and are shown in the raw data for each parameter. The dashed and dotted lines show the bounds, upper and lower, respectively, and the open symbols indicate data points taken after a 1 week room temperature anneal. In calculating confidence levels, KTL values of 3.972 were used because there are seven parts in each bias group.

Gate Reverse Current

The datasheet specifies a maximum gate current of -150 pA with the gate source voltage $V_{GS} = -15\text{ V}$ and the drain source voltage $V_{DS} = 0\text{ V}$. Figure 4 shows the diagram of the circuit used to make this measurement.

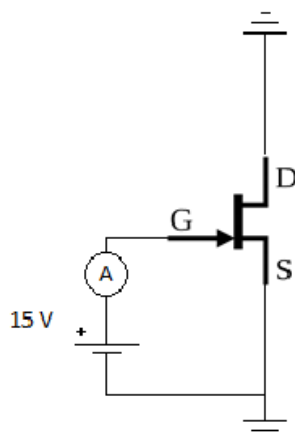


Figure 4: Gate Reverse Current measurement circuit

All devices stayed within specification throughout irradiation. The average response of the devices can be seen below in Figure 5, raw data in Table 5 and statistics in Table 6.

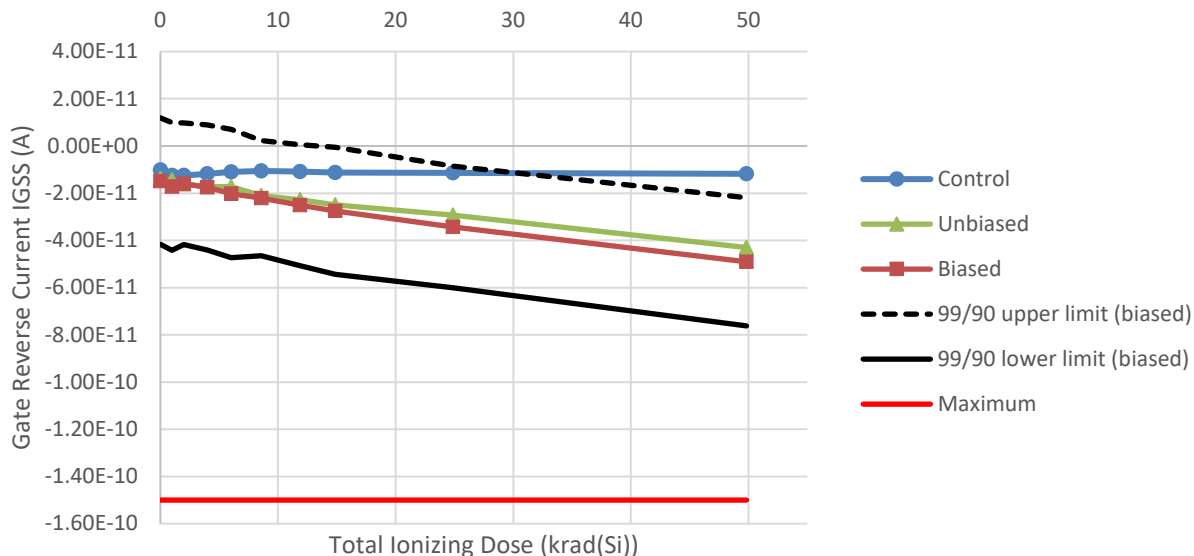


Figure 5: Gate Reverse Current for 3 irradiation/bias conditions. Datasheet specification limit shown by red line.

	DUT #	0 krad	1 krad	2 krad	4 krad	6 krad	9 krad	12 krad	15 krad	25 krad	50 krad	Unit
CONTROLS	10	-1.04E-11	-1.43E-11	-1.43E-11	-1.30E-11	-1.12E-11	-1.09E-11	-1.11E-11	-1.17E-11	-1.14E-11	-1.17E-11	A
	11	-9.95E-12	-1.07E-11	-1.05E-11	-1.05E-11	-1.09E-11	-1.03E-11	-1.05E-11	-1.09E-11	-1.14E-11	-1.20E-11	A
Un - Biased	12	-1.35E-11	-1.05E-11	-1.31E-11	-1.43E-11	-1.37E-11	-1.79E-11	-1.89E-11	-2.26E-11	-2.69E-11	-3.95E-11	A
	13	-3.02E-11	-3.02E-11	-3.45E-11	-3.33E-11	-3.27E-11	-3.78E-11	-3.95E-11	-4.15E-11	-4.42E-11	-5.99E-11	A
	14	-1.01E-11	-1.09E-11	-1.39E-11	-1.46E-11	-1.41E-11	-1.79E-11	-1.94E-11	-2.11E-11	-2.65E-11	-3.90E-11	A
	15	-1.01E-11	-1.15E-11	-1.18E-11	-1.47E-11	-1.44E-11	-1.83E-11	-2.03E-11	-2.23E-11	-2.82E-11	-4.04E-11	A
	16	-1.05E-11	-1.15E-11	-1.43E-11	-1.54E-11	-1.51E-11	-1.91E-11	-2.08E-11	-2.34E-11	-2.56E-11	-4.30E-11	A
	17	-1.02E-11	-1.28E-11	-1.19E-11	-1.37E-11	-1.52E-11	-1.90E-11	-2.22E-11	-2.32E-11	-2.85E-11	-4.30E-11	A
	18	-1.25E-11	-1.30E-11	-1.34E-11	-1.47E-11	-1.54E-11	-1.70E-11	-1.86E-11	-2.08E-11	-2.54E-11	-3.63E-11	A
Biased -10V	19	-1.14E-11	-1.45E-11	-1.30E-11	-1.49E-11	-1.65E-11	-1.93E-11	-2.19E-11	-2.41E-11	-3.07E-11	-4.63E-11	A
	20	-1.25E-11	-1.35E-11	-1.16E-11	-1.32E-11	-1.49E-11	-1.74E-11	-1.96E-11	-2.20E-11	-2.77E-11	-3.96E-11	A
	21	-1.17E-11	-1.49E-11	-1.37E-11	-1.57E-11	-1.95E-11	-2.07E-11	-2.35E-11	-2.64E-11	-3.44E-11	-5.17E-11	A
	22	-1.22E-11	-1.28E-11	-1.17E-11	-1.31E-11	-1.63E-11	-1.82E-11	-2.10E-11	-2.27E-11	-3.04E-11	-4.44E-11	A
	23	-3.12E-11	-3.35E-11	-3.15E-11	-3.34E-11	-3.64E-11	-3.65E-11	-4.02E-11	-4.31E-11	-4.91E-11	-6.27E-11	A
	24	-1.08E-11	-1.36E-11	-1.46E-11	-1.44E-11	-1.72E-11	-1.92E-11	-2.37E-11	-2.46E-11	-3.24E-11	-4.66E-11	A
	25	-1.43E-11	-1.73E-11	-1.62E-11	-1.81E-11	-2.02E-11	-2.34E-11	-2.58E-11	-2.93E-11	-3.54E-11	-5.21E-11	A

Table 5: Raw data for Gate reverse current measurements

Target Dose	Actual Dose (kiloRoentgens)	Actual Dose (krad(Si))	Control	Stdev	Unbiased	Stdev	99/90 upper limit (unbiased)	99/90 lower limit (unbiased)	Biased	Stdev	99/90 upper limit (biased)	99/90 lower limit (biased)	Maximum
0	0.00	0.00	-1.02E-11	2.25E-13	-1.39E-11	6.78E-12	1.31E-11	-4.08E-11	-1.49E-11	6.74E-12	1.19E-11	-4.17E-11	-1.50E-10
1	1.14	0.99	-1.25E-11	1.80E-12	-1.43E-11	6.53E-12	1.16E-11	-4.03E-11	-1.72E-11	6.81E-12	9.88E-12	-4.42E-11	-1.50E-10
2	2.29	1.99	-1.25E-11	1.90E-12	-1.61E-11	7.55E-12	1.39E-11	-4.61E-11	-1.60E-11	6.48E-12	9.72E-12	-4.18E-11	-1.50E-10
4	4.59	3.97	-1.18E-11	1.25E-12	-1.72E-11	6.57E-12	8.86E-12	-4.33E-11	-1.75E-11	6.66E-12	8.92E-12	-4.40E-11	-1.50E-10
6	6.94	6.01	-1.11E-11	1.50E-13	-1.72E-11	6.34E-12	7.96E-12	-4.24E-11	-2.01E-11	6.85E-12	7.08E-12	-4.74E-11	-1.50E-10
9	9.90	8.57	-1.06E-11	3.00E-13	-2.10E-11	6.89E-12	6.37E-12	-4.84E-11	-2.21E-11	6.15E-12	2.32E-12	-4.65E-11	-1.50E-10
12	13.71	11.86	-1.08E-11	3.00E-13	-2.28E-11	6.91E-12	4.62E-12	-5.02E-11	-2.51E-11	6.44E-12	4.80E-13	-5.07E-11	-1.50E-10
15	17.16	14.86	-1.13E-11	4.00E-13	-2.50E-11	6.80E-12	2.04E-12	-5.20E-11	-2.75E-11	6.77E-12	-5.57E-13	-5.44E-11	-1.50E-10
25	28.75	24.88	-1.14E-11	0.00E+00	-2.93E-11	6.17E-12	-4.83E-12	-5.38E-11	-3.43E-11	6.50E-12	-8.49E-12	-6.01E-11	-1.50E-10
50	57.57	49.83	-1.19E-11	1.50E-13	-4.30E-11	7.23E-12	-1.43E-11	-7.17E-11	-4.91E-11	6.84E-12	-2.19E-11	-7.62E-11	-1.50E-10

Table 6: Statistics for Gate Reverse Current measurements

Gate Source Cutoff Voltage

The datasheet specifies a minimum Gate Source Cutoff Voltage of $V_{GS(OFF)} = -1$ V and a maximum of $V_{GS(OFF)} = -4$ V where the device is considered off when the drain current $I_D < 1$ nA with drain-source voltage $V_{DS} = 10$ V. Figure 6 shows the diagram of the circuit used to make this measurement.

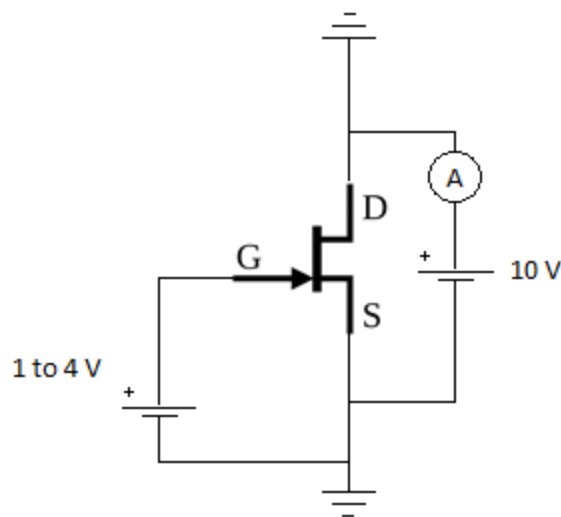


Figure 6: Gate Source Cutoff Voltage measurement circuit

All devices stayed within specification throughout irradiation. The average response of the devices can be seen below in Figure 7, raw data in Table 7 and statistics in Table 8.

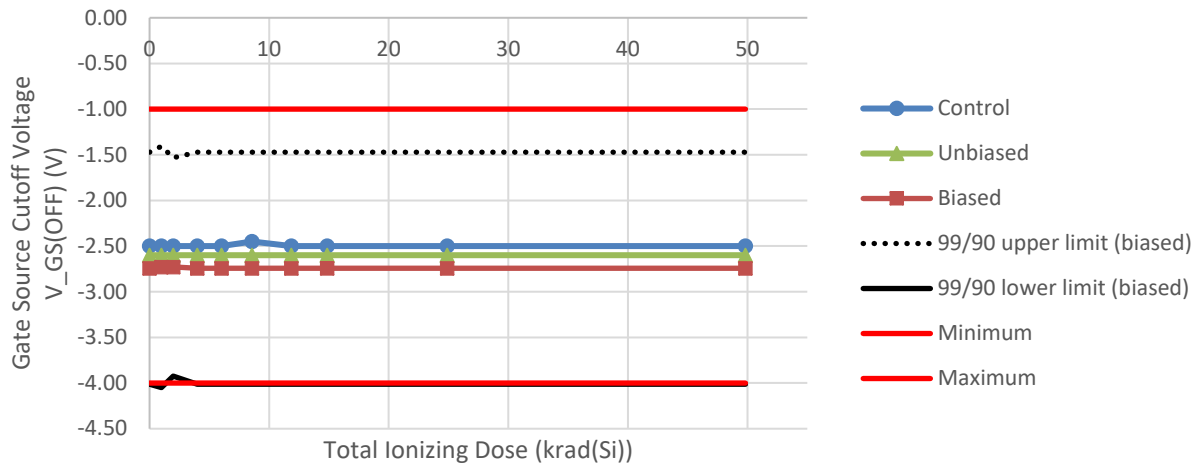


Figure 7: Gate Source Cutoff Voltage for 3 irradiation/bias conditions. Datasheet specification limit shown by red line.

	DUT #	0 krad	1 krad	2 krad	4 krad	6 krad	9 krad	12 krad	15 krad	25 krad	50 krad	Unit
CONTROLS	10	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	V
	11	-2.7	-2.7	-2.7	-2.7	-2.7	-2.6	-2.7	-2.7	-2.7	-2.7	V
Un - Biased	12	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	V
	13	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	V
	14	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	V
	15	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3	V
	16	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	V
	17	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	V
	18	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	V
Biased -10V	19	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	V
	20	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4	V
	21	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	-2.6	V
	22	-2.5	-2.4	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5	V
	23	-3.2	-3.2	-3.1	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	-3.2	V
	24	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	V
	25	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	-3.1	V

Table 7: Raw data for Gate Source Cutoff Voltage

Target Dose	Actual Dose (kiloRoentgens)	Actual Dose (krad(Si))	Control	Stdev	Unbiased	Stdev	99/90 upper limit (unbiased)	99/90 lower limit (unbiased)	Biased	Stdev	99/90 upper limit (biased)	99/90 lower limit (biased)	Minimum	Maximum
0.00	0.00	0.00	-2.50	0.20	-2.60	0.23	-1.67	-3.53	-2.74	0.32	-1.47	-4.01	-1.00	-4
1.00	1.14	0.99	-2.50	0.20	-2.60	0.23	-1.67	-3.53	-2.73	0.33	-1.41	-4.05	-1.00	-4
2.00	2.29	1.99	-2.50	0.20	-2.60	0.23	-1.67	-3.53	-2.73	0.30	-1.53	-3.92	-1.00	-4
4.00	4.59	3.97	-2.50	0.20	-2.60	0.23	-1.67	-3.53	-2.74	0.32	-1.47	-4.01	-1.00	-4
6.00	6.94	6.01	-2.50	0.20	-2.60	0.23	-1.67	-3.53	-2.74	0.32	-1.47	-4.01	-1.00	-4
9.00	9.90	8.57	-2.45	0.15	-2.60	0.23	-1.67	-3.53	-2.74	0.32	-1.47	-4.01	-1.00	-4
12.00	13.71	11.86	-2.50	0.20	-2.60	0.23	-1.67	-3.53	-2.74	0.32	-1.47	-4.01	-1.00	-4
15.00	17.16	14.86	-2.50	0.20	-2.60	0.23	-1.67	-3.53	-2.74	0.32	-1.47	-4.01	-1.00	-4
25.00	28.75	24.88	-2.50	0.20	-2.60	0.23	-1.67	-3.53	-2.74	0.32	-1.47	-4.01	-1.00	-4
50.00	57.57	49.83	-2.50	0.20	-2.60	0.23	-1.67	-3.53	-2.74	0.32	-1.47	-4.01	-1.00	-4

Table 8: Statistics for Gate Source Cutoff Voltage

Drain Saturation Current

The datasheet specifies a minimum Drain Saturation Current of $I_{DSS} = 12\text{mA}$ and a maximum of $I_{DSS} = 30\text{mA}$ with drain-source voltage $V_{DS} = 10\text{V}$ and the gate source voltage $V_{GS} = 0\text{V}$. Figure 8 shows the diagram of the circuit used to make this measurement.

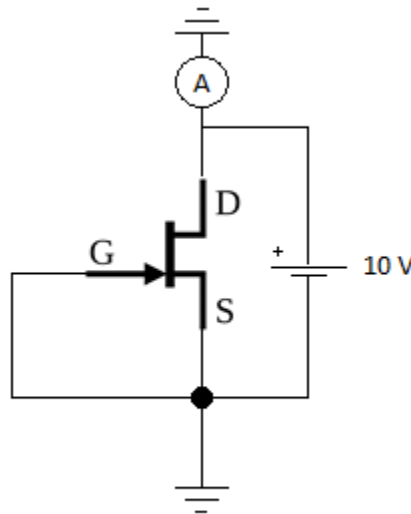


Figure 8: Drain Saturation Current measurement circuit

All devices stayed within specification throughout irradiation. The average response of the devices can be seen below in Figure 9, raw data in Table 9 and statistics in Table 10.

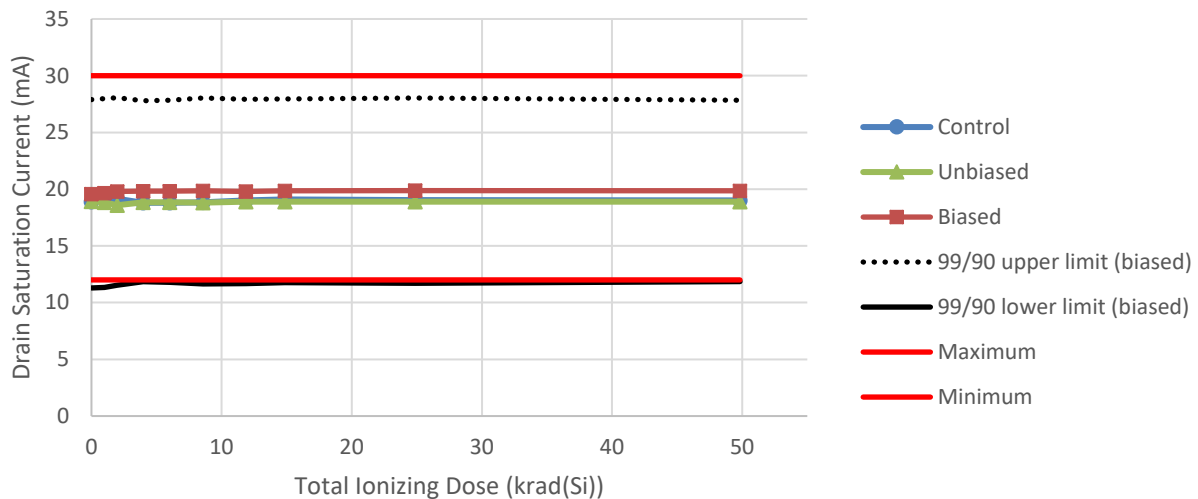


Figure 9: Drain Saturation Current for 3 irradiation/bias conditions. Datasheet specification limit shown by red line.

	DUT #	0 krad	1 krad	2 krad	4 krad	6 krad	9 krad	12 krad	15 krad	25 krad	50 krad	Unit
CONTROLS	10	16.5	16.9	16.3	16.6	16.6	16.7	16.8	16.9	16.9	16.9	mA
	11	21.3	21.4	20.9	21	21	21	21.2	21.3	21.2	21.1	mA
Un - Biased	12	17	16.8	16.4	16.8	16.7	16.7	16.9	16.8	16.8	16.8	mA
	13	17.5	17.7	17.1	17.5	17.5	17.4	17.5	17.5	17.6	17.5	mA
	14	20.6	20.6	20.4	20.8	20.5	20.6	20.7	20.7	20.6	20.7	mA
	15	16.5	16.3	16.1	16.2	16.4	16.4	16.4	16.6	16.4	16.3	mA
	16	19.1	19.2	18.7	19	19	19	19.1	19.1	19	19.2	mA
	17	19.8	19.3	19.6	19.6	19.6	19.6	19.6	19.6	19.7	19.7	mA
Biased -10V	18	22	22	21.8	22	22.1	22	22.1	22	22.1	22	mA
	19	17.7	17.8	18.1	18.1	18.2	18.2	18.1	18.2	18.2	18.1	mA
	20	16.9	17	17.2	17.3	17.2	17.2	17.2	17.2	17.3	17.3	mA
	21	19.4	19.3	19.6	19.6	19.7	19.6	19.7	19.6	19.6	19.6	mA
	22	18.7	18.9	18.7	18.9	18.9	18.8	18.8	19	18.8	19	mA
	23	19.7	19.6	19.7	19.7	19.7	19.8	19.6	19.8	19.8	19.9	mA
	24	23.7	23.8	23.9	23.8	23.9	23.9	23.8	23.9	23.9	23.9	mA
	25	21	21.2	21.4	21.3	21.1	21.4	21.4	21.3	21.5	21.1	mA

Table 9: Raw data for Drain Saturation Current

Target Dose	Actual Dose (kiloRoentgens)	Actual Dose (krad(Si))	Control	Stdev	Unbiased	Stdev	99/90 upper limit (unbiased)	99/90 lower limit (unbiased)	Biased	Stdev	99/90 upper limit (biased)	99/90 lower limit (biased)	Maximum	Minimum
0.00	0.00	0.00	18.90	2.40	18.93	1.88	26.39	11.47	19.59	2.09	27.88	11.29	30	12
1.00	1.14	0.99	19.15	2.25	18.84	1.90	26.40	11.29	19.66	2.10	27.98	11.33	30	12
2.00	2.29	1.99	19.15	2.30	18.59	1.99	26.51	10.67	19.80	2.08	28.06	11.54	30	12
4.00	4.59	3.97	18.80	2.20	18.84	1.98	26.70	10.99	19.81	2.01	27.79	11.84	30	12
6.00	6.94	6.01	18.80	2.20	18.83	1.94	26.53	11.13	19.81	2.02	27.85	11.78	30	12
9.00	9.90	8.57	18.85	2.15	18.81	1.94	26.51	11.12	19.84	2.06	28.03	11.66	30	12
12.00	13.71	11.86	19.00	2.20	18.90	1.94	26.59	11.21	19.80	2.04	27.92	11.68	30	12
15.00	17.16	14.86	19.10	2.20	18.90	1.89	26.41	11.39	19.86	2.04	27.95	11.77	30	12
25.00	28.75	24.88	19.05	2.15	18.89	1.93	26.56	11.21	19.87	2.05	28.03	11.72	30	12
50.00	57.57	49.83	19.00	2.10	18.89	1.95	26.64	11.13	19.84	2.01	27.83	11.85	30	12

Table 10: Statistics for Drain Saturation Current

10. 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) DATASHEET <http://interfet.com/datasheet/U309/>