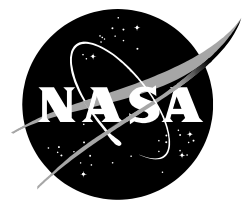


NASA/TM–20210018675



Texas Instruments' LP2951 Voltage Regulator Total Ionizing Dose Test Report

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July 2021

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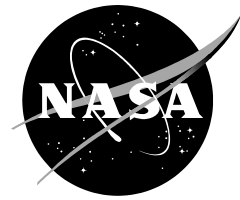
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*Test Date: 21 September 2020
Report Date: 10 June 2021*

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July 2021

Acknowledgments

This work was sponsored by the NASA GSFC Radiation Effects and Analysis Group and supported by the LUCY mission.

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1. INTRODUCTION

The purpose of this test was to characterize Texas Instruments' LP2951 voltage regulator's parameter degradation for total dose response. In the test, the device was exposed to low dose rate (LDR) irradiations using gamma radiation. Device parameters such as output voltage, line regulation, and bias current were investigated.

2. DEVICES TESTED

2.1. Part Background

The LP2951 is a low power voltage regulator. It features a low quiescent current and dropout voltage and an error flag output. The part can be pin-strapped for 5V, 3V, or 3.3V or programmed from 1.24V to 29V with an external pair of resistors.

2.2. Device Under Test (DUT) Information

Ten (10) parts total were tested for TID response. Eight (8) parts were irradiated and two (2) were used as controls. All specifications and descriptions are according to the datasheet (rev A). More information can be found in Table 1.

Table 1. Part Identification Information

Part Number	LP2951
Flight Part Number	5962-3870501BPA
Manufacturer	Texas Instruments
Lot Date Code	1911A
Quantity Tested	8
Part Function	Linear Regulator
Part Technology	Bipolar
Package	CDIP 8-pin

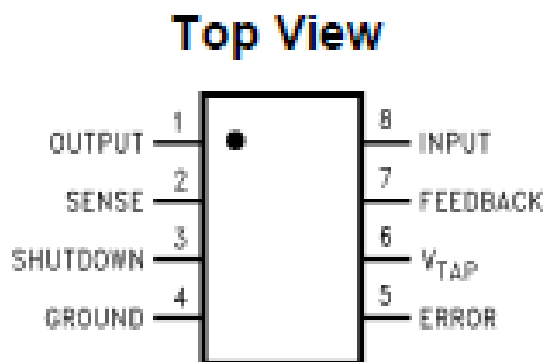


Fig. 1. Picture of pinout of device

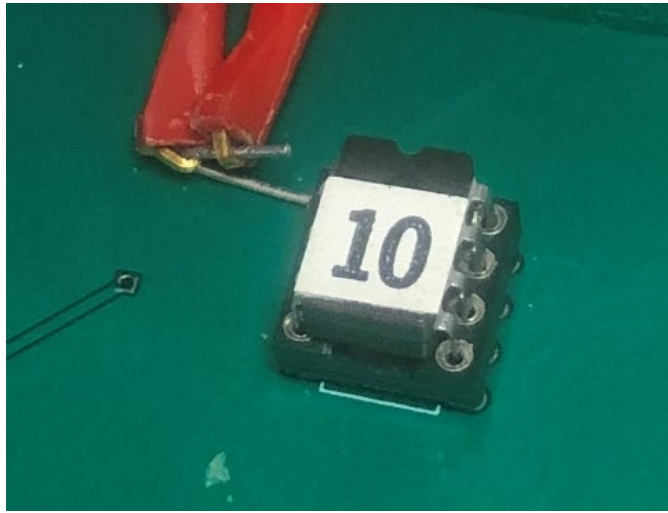


Fig. 2. Picture of device

3. TEST SETUP

Two sockets (ZIF and DIP) were used on the test board, to measure all the parameters. Three (3) Keithley 2400s and one HP 34401A multimeter were used to measure parameters on each DUT. A custom LabVIEW program automated the test, collected data, and stored the data for later analysis.

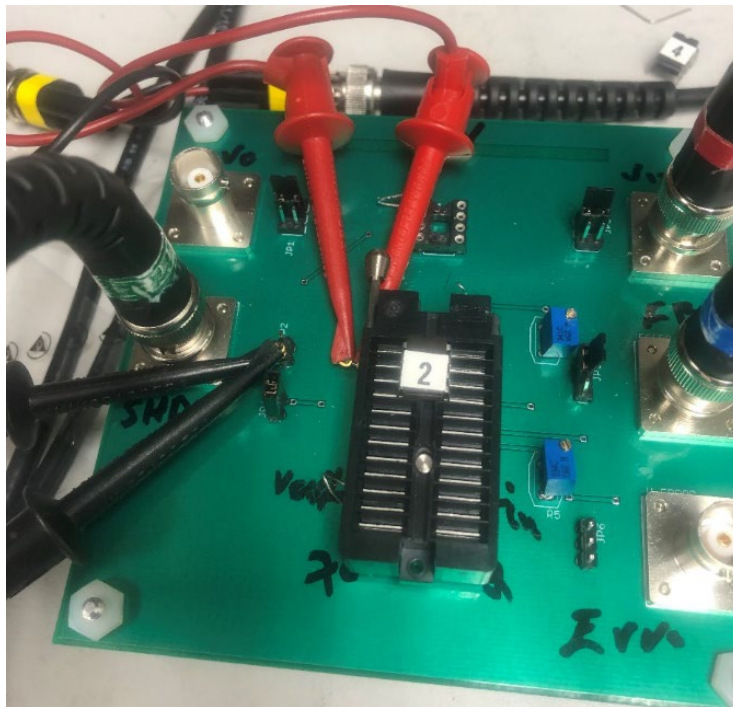


Fig. 3. Picture of DUT on test board

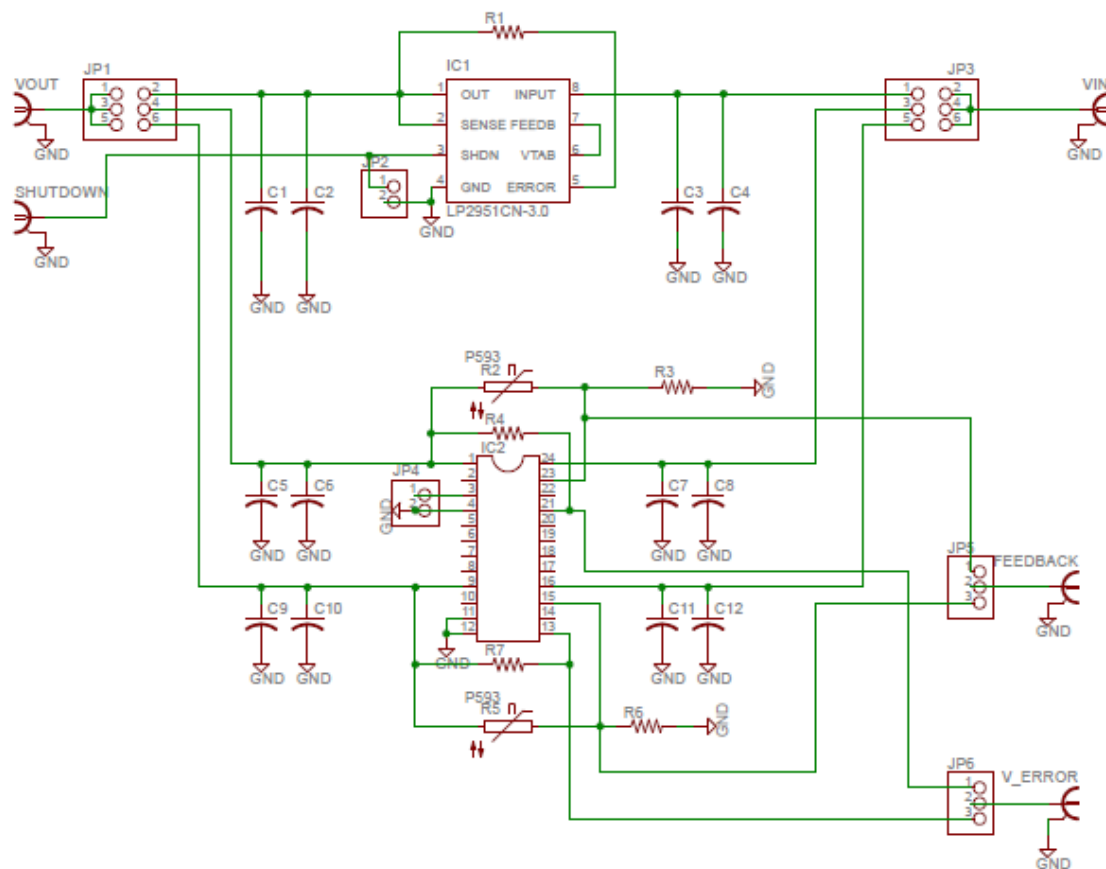


Fig. 4. Schematic of test board

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 low dose rate. Ten parts were tested, eight exposed to radiation and two were used as controls. Prior to the first radiation dose, all ten 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. Three parts were biased at 5V, three parts were biased at 3.3V, and two were unbiased during the irradiation steps. See Table 2 for more information.

Table 2. Device Grouping

Group	Qty	Bias	Dose Rate	Exposure Level Steps (krad(Si))
1	3	Biased 5V	10 mrad(Si)/s	0, 1, 2.5, 5.9, 7.5, 8.5, 10.8, 12.4, 14, 16.3
2	3	Biased 3.3V	10 mrad(Si)/s	0, 1, 2.5, 5.9, 7.5, 8.5, 10.8, 12.4, 14, 16.3
3	2	Unbiased	10 mrad(Si)/s	0, 1, 2.5, 5.9, 7.5, 8.5, 10.8, 12.4, 14, 16.3

The parts were placed in ZIF socket adapter on a wire wrapped board. Table 3 describes the exact pinout of a biased part.

Table 3. Biased DUT pinout

PIN#	SIGNAL	VOLTAGE
1	OUTPUT	5 or 3.3V
2	SENSE	-
3	SHUTDOWN	-
4	GND	GND
5	ERROR	-
6	VTAP	-
7	FEEDBACK	-
8	INPUT	6 or 4.3V

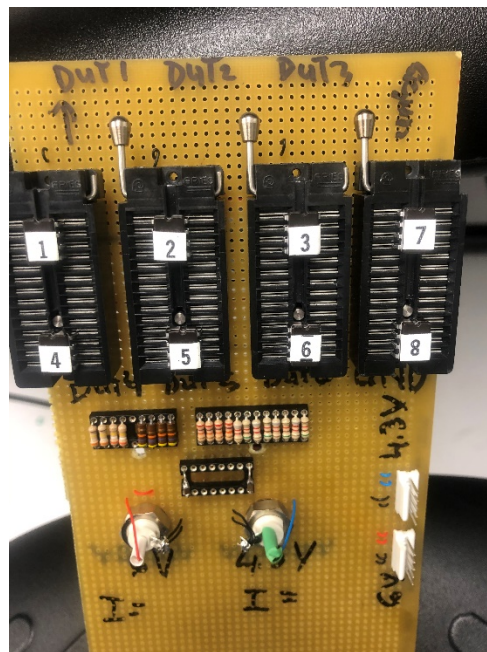


Fig. 5. LP2951 bias board

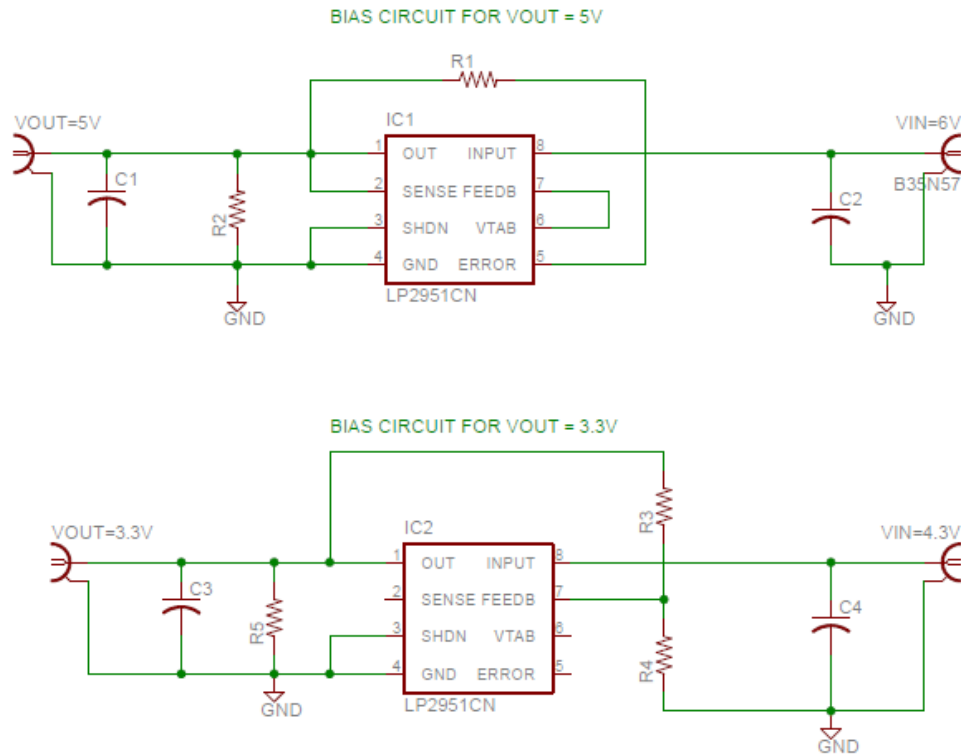


Fig. 6. LP2951 Bias Board Schematics

4.2 Electrical Tests

Specification thresholds were set in accordance with the LP2951 datasheet.

All data from the DC electrical tests in Table 4 were logged in excel spreadsheet files using three Keithley 2400s and an HP 34401A multimeter. Data for all parts were measured and logged.

Table 4. List of Electrical Tests Performed

Symbol	Parameter	MIN	TYP	MAX	Units	Test Conditions
V _O	Output Voltage (+5V)	4.975		5.025	V	V _{IN} = 6V, I _L = -100uA, V _O = 5V
V _O	Output Voltage (+3.3V)				V	V _{IN} = 6V, I _L = -100uA, V _O = 3.3V
V _{O Line}	Line Regulation	-5		5	mV	V _{IN} = 6V, 11V, 16V, 21V, I _L = -1mA, V _O = 5V
V _{O Line}	Line Regulation	-5		5	mV	V _{IN} = 4.3V, 9.3V, 14.3V, 19.3V, I _L = -1mA, V _O = 3.3V
V _{O Load}	Load Regulation	-5		5	mV	V _{IN} = 6V, I _L = 20mA, 50mA, 75mA, 100mA, V _O = 5V
V _{O Load}	Load Regulation	-5		5	mV	V _{IN} = 6V, I _L = 20mA, 50mA, 75mA, 100mA V _O = 3.3V
I _G	Ground Current			120	uA	I _L = 100uA, V _O = 5V, V _O = 3.3V
I _G	Ground Current			12	mA	I _L = 100mA, V _O = 5V, V _O = 3.3V
I _{GDO}	Dropout Ground Current			170	uA	V _O = 5V, V _O = 3.3V
I _{SC}	Current Limit			0.2	A	V _O = 5V, V _O = 3.3V
I _{FB}	Feedback Pin Bias Current			40	nA	V _O = 5V, V _O = 3.3V
V _{OL}	Error Comparator Output Low Voltage			250	mV	V _O = 5V, V _O = 3.3V
I _{SD}	Shutdown Pin Input Current			50	uA	V _O = 5V, V _O = 3.3V, V _{SD} = 2.4V
I _{SD}	Shutdown Pin Input Current			600	uA	V _O = 5V, V _O = 3.3V, V _{SD} = 30V
I _{LKG}	Regular Output Bias Current in Shutdown	-10		10	uA	V _{IN} = 30V, V _O = 5V, V _O = 3.3V, V _{SD} = 2V
V _D	Dropout Voltage			80	mV	V _O = 5V, V _O = 3.3V, I _L = 100uA
V _D	Dropout Voltage			450	mV	V _O = 5V, V _O = 3.3V, I _L = 100mA
V _{TH L}	Error Comparator Lower Threshold Voltage			0.384, 0.254	V	V _O = 5V, V _O = 3.3V
V _{TH H}	Error Comparator Upper Threshold Voltage			40	mV	V _O = 5V, V _O = 3.3V
V _{REF}	Reference Voltage	1.218		1.252	V	V _{IN} = 2.3V, 4.3V, 6.3V, 8.3V, 10.3V, 12.3V, 14.3V, 16.3, I _L = 100uA, I _L = 100mA

5. FAILURE CRITERIA

The parameter limits are defined as those listed in the LP2951 datasheet. If functional failure was observed for any of the steps, those results were noted and compared relative to the dosing step and the individual device's previous dose step measurements.

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

All parts were tested to 16.3 krad(Si). Output voltage went out of specification between 2.5 and 5.9 krad(Si) when biased with 5 V and between 5.9 and 7.5 krad(Si) when biased with 3.3 V. The load regulation went out of specification between 12.4 and 14 krad(Si) (at 5 V and $I_L = 100$ mA) and 10.8 and 12.4 krad(Si) (at 3.3 V and $I_L = 100$ mA). The load regulation for the unbiased parts also went out of specification for 3.3 V and 75 mA between 14 and 16.3 krad(Si). All of the other parts stayed in specification. Ground current went out of specification (with the conditions 5 V and $I_L = 100$ mA) between 8.5 and 12.4 krad(Si) and (with the conditions 3.3 V and $I_L = 100$ mA) between 8.5 and 10.8 krad(Si). Figures below show results of all tested parameters.

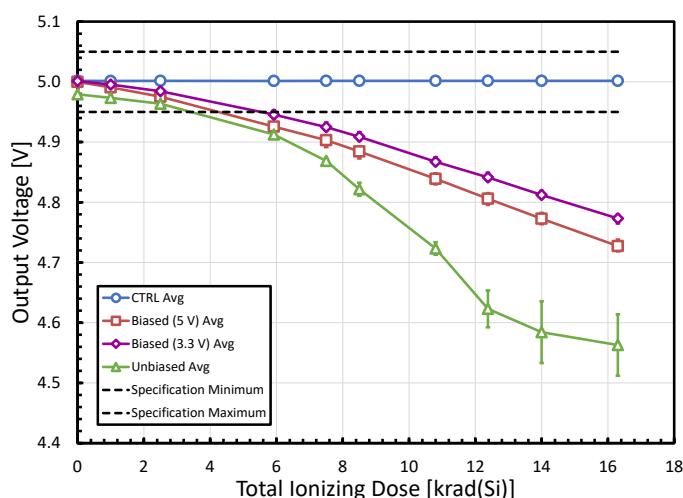


Fig. 7. 5-V Output Voltage over dose.

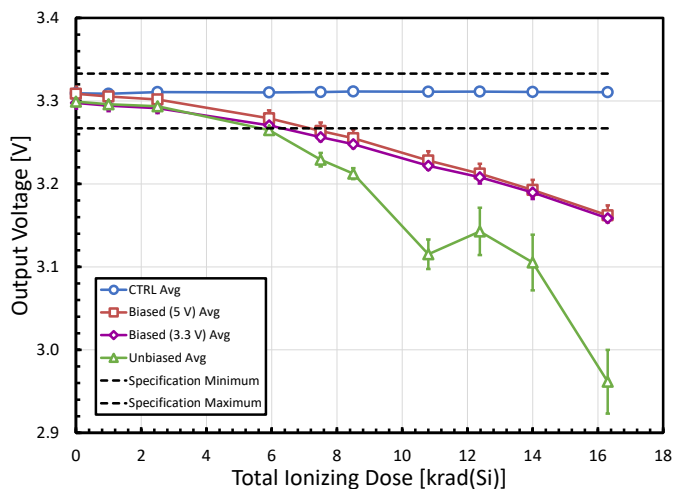


Fig. 8. 3.3-V Output Voltage over dose.

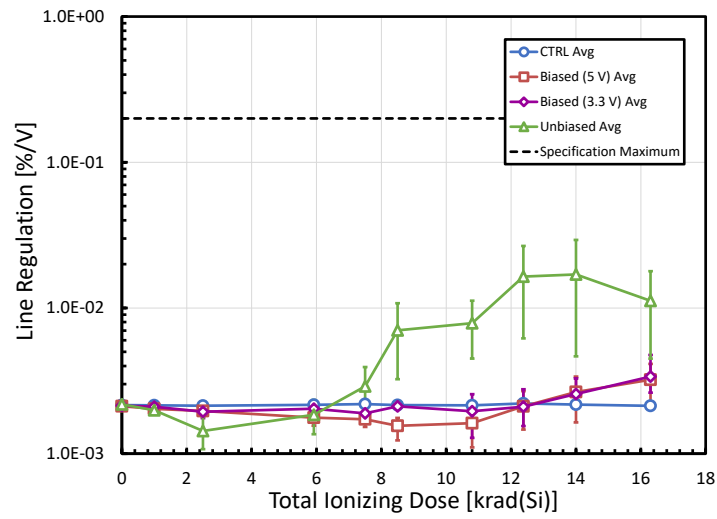


Fig. 9. 5-V Line Regulation (6 V) over dose.

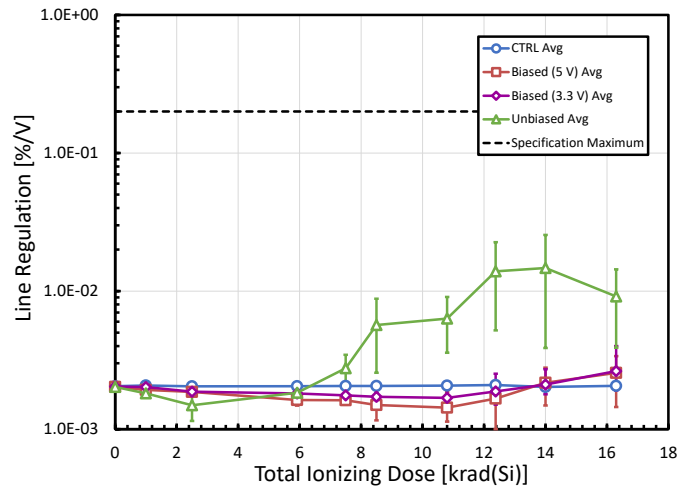


Fig. 10. 5-V Line Regulation (11 V) over dose.

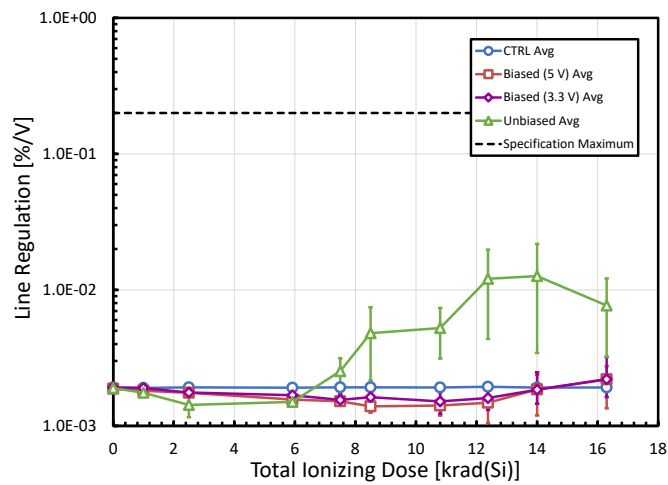


Fig. 11. 5-V Line Regulation (16 V) over dose.

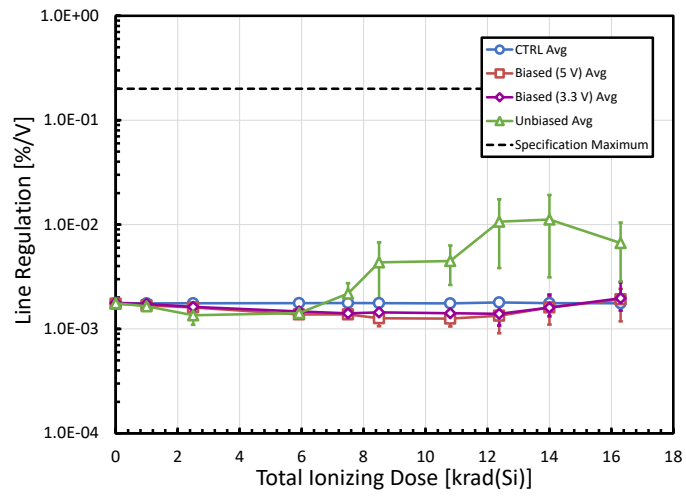


Fig. 12. 5-V Line Regulation (21 V) over dose.

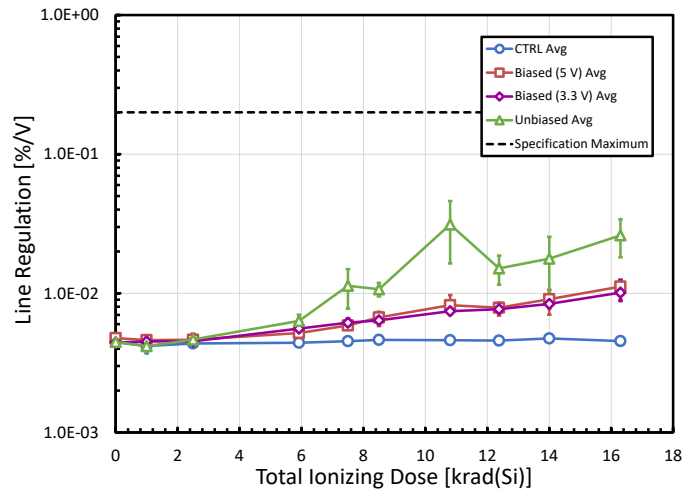


Fig. 13. 3.3-V Line Regulation (4.3 V) over dose.

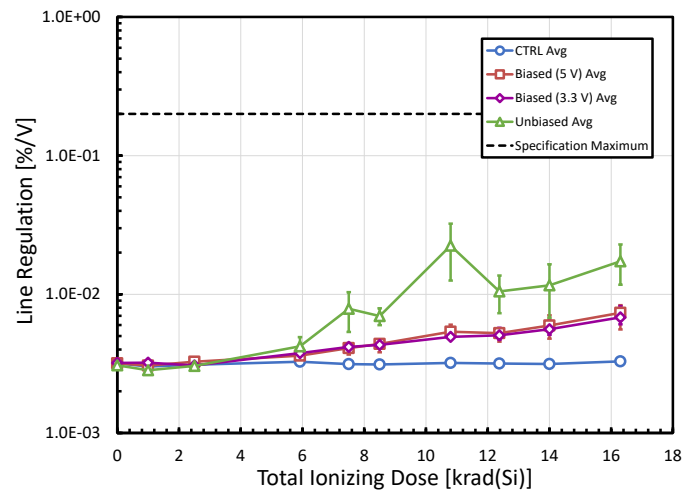


Fig. 14. 3.3-V Line Regulation (9.3 V) over dose.

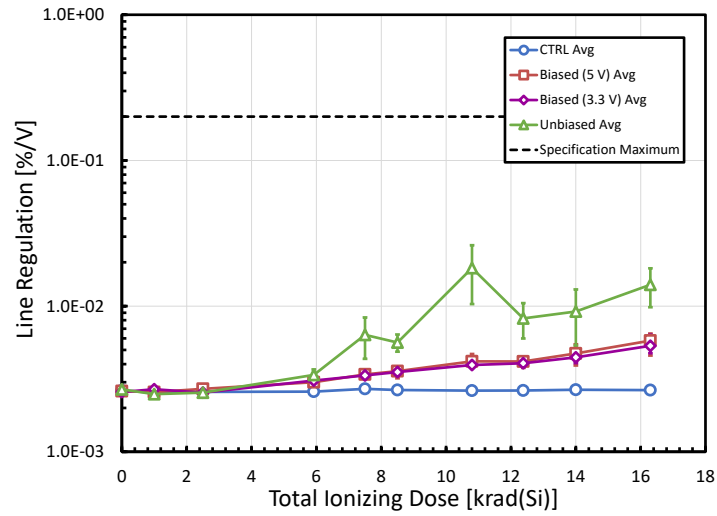


Fig. 15. 3.3-V Line Regulation (14.3 V) over dose.

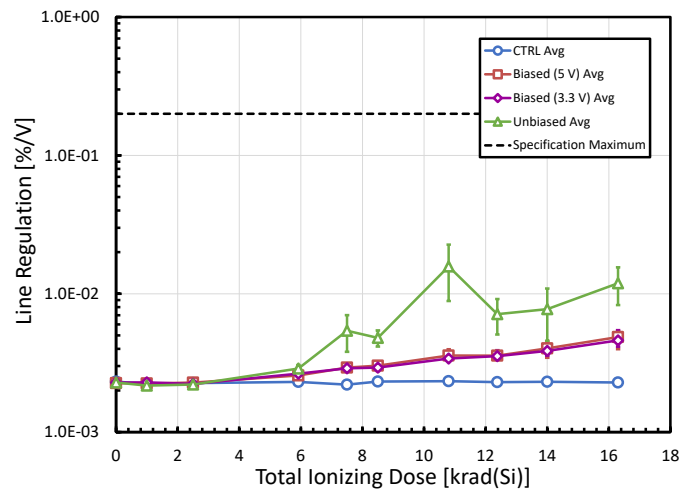


Fig. 16. 3.3-V Line Regulation (19.3 V) over dose.

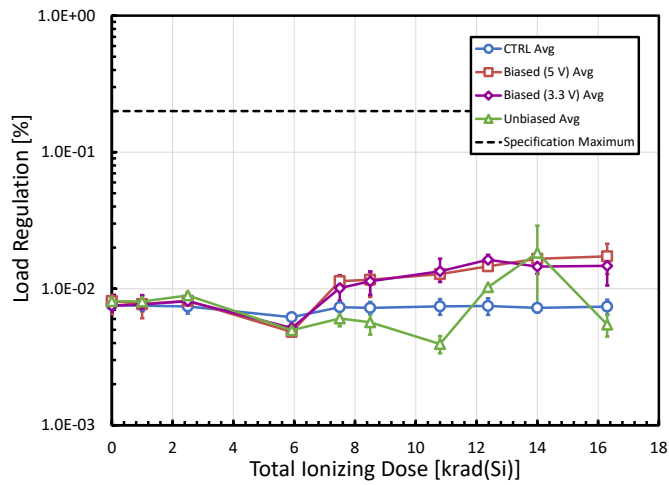


Fig. 17. 5-V Load Regulation (20 mA) over dose.

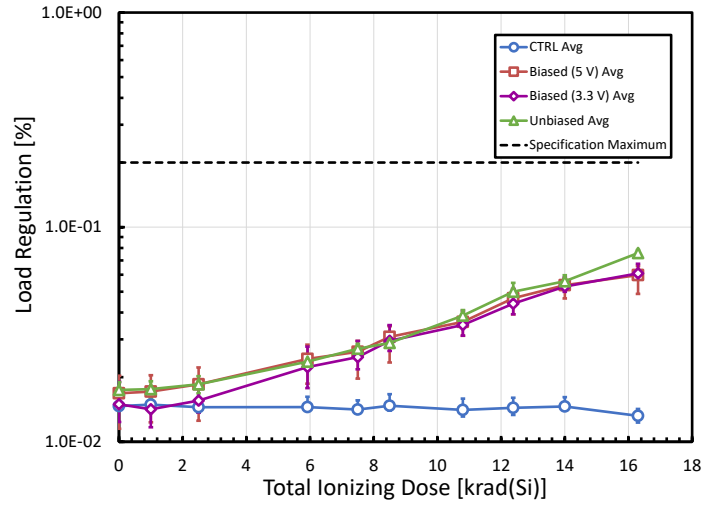


Fig. 18. 5-V Load Regulation (50 mA) over dose.

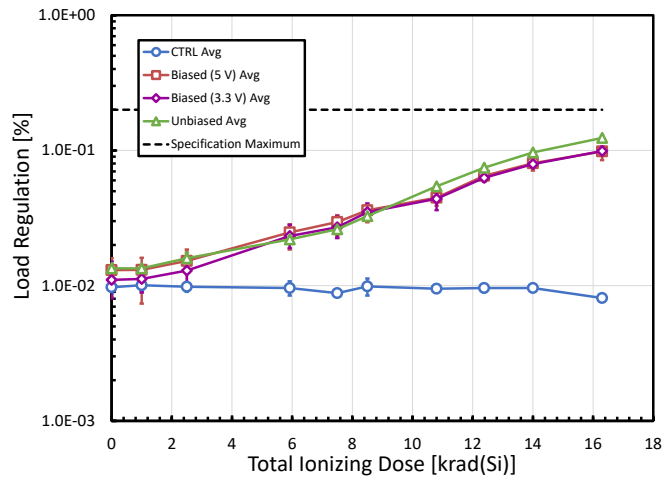


Fig. 19. 5-V Load Regulation (75 mA) over dose.

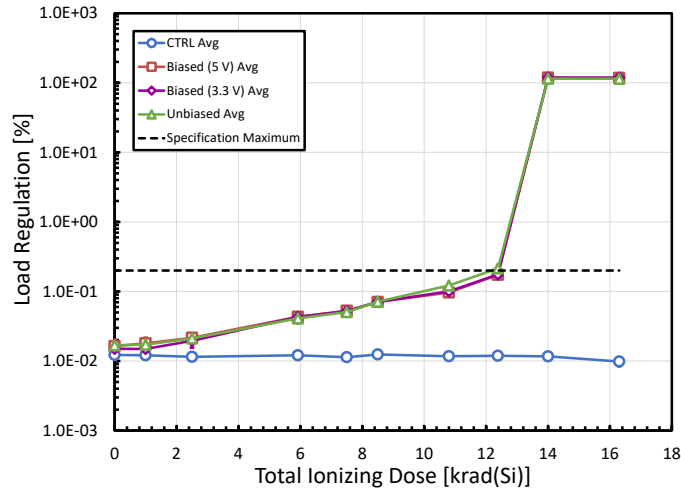


Fig. 20. 5-V Load Regulation (100 mA) over dose.

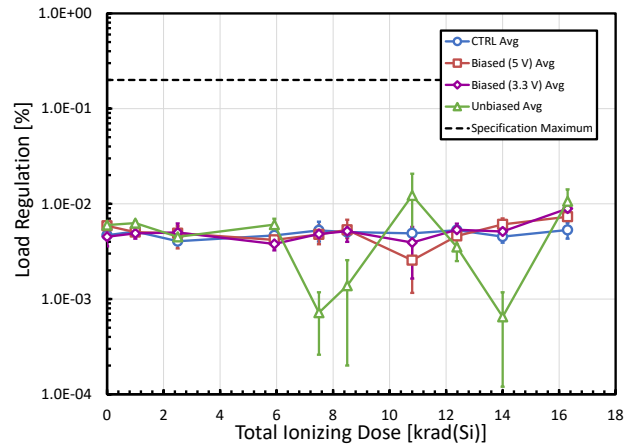


Fig. 21. 3.3-V Load Regulation (20 mA) over dose.

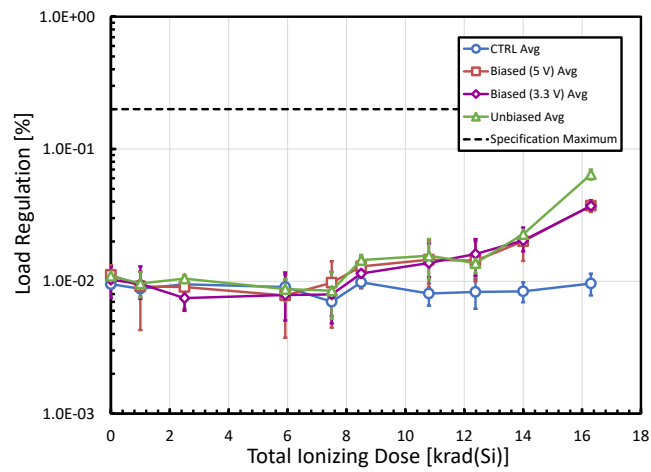


Fig. 22. 3.3-V Load Regulation (50 mA) over dose.

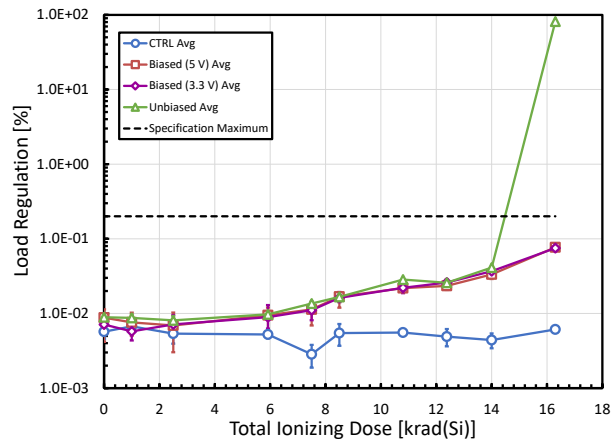


Fig. 23. 3.3-V Load Regulation (75 mA) over dose.

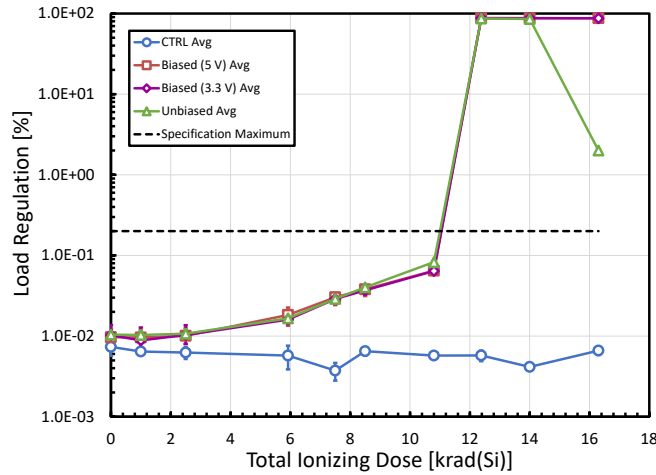


Fig. 24. 3.3-V Load Regulation (100 mA) over dose.

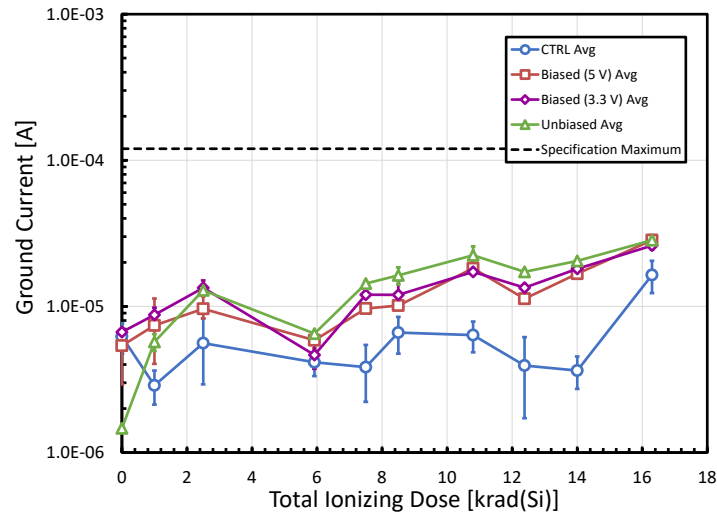


Fig. 25. 5-V Current Ground (100 uA) over dose.

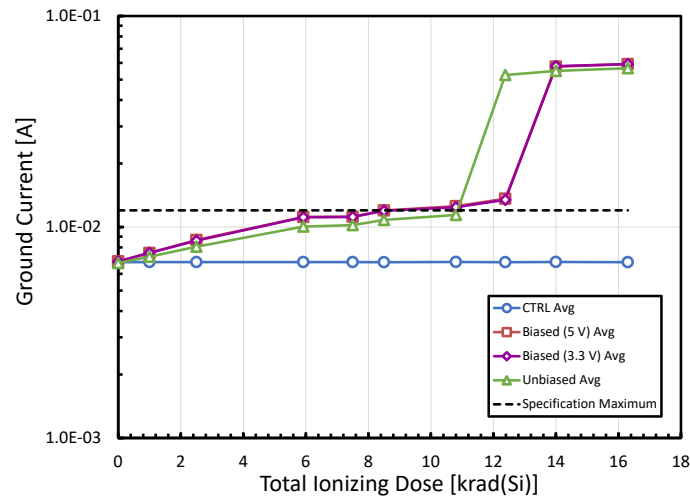


Fig. 26. 5-V Current Ground (100 mA) over dose.

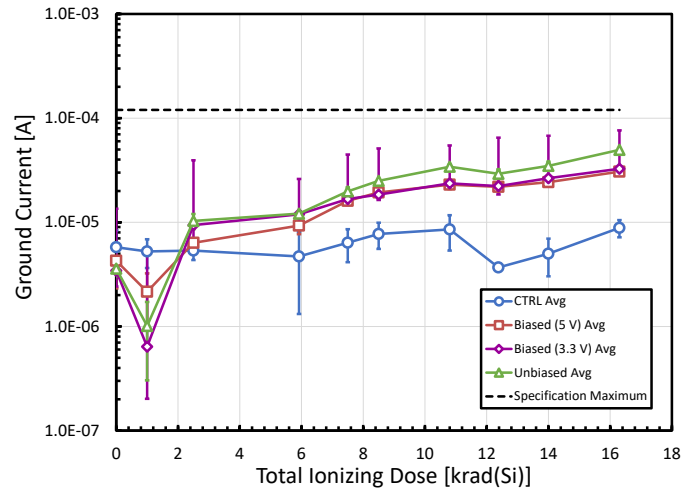


Fig. 27. 3.3-V Current Ground (100 uA) over dose.

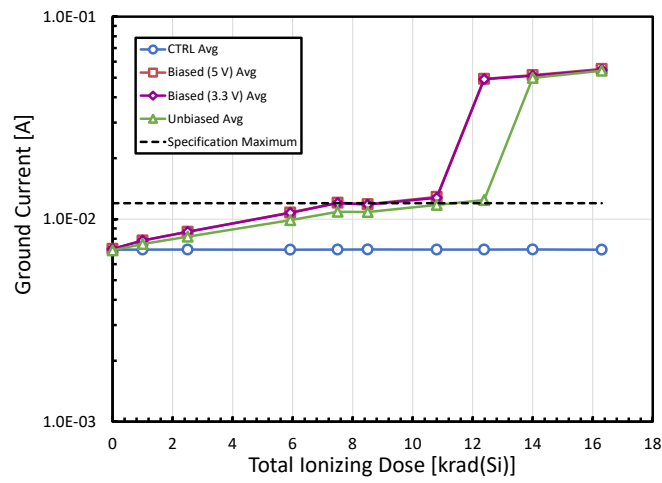


Fig. 28. 3.3-V Current Ground (100 mA) over dose.

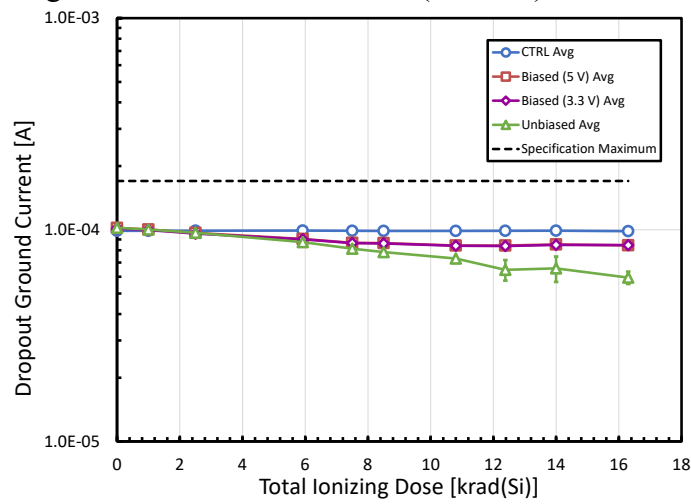


Fig. 29. 5-V Current Dropout over dose.

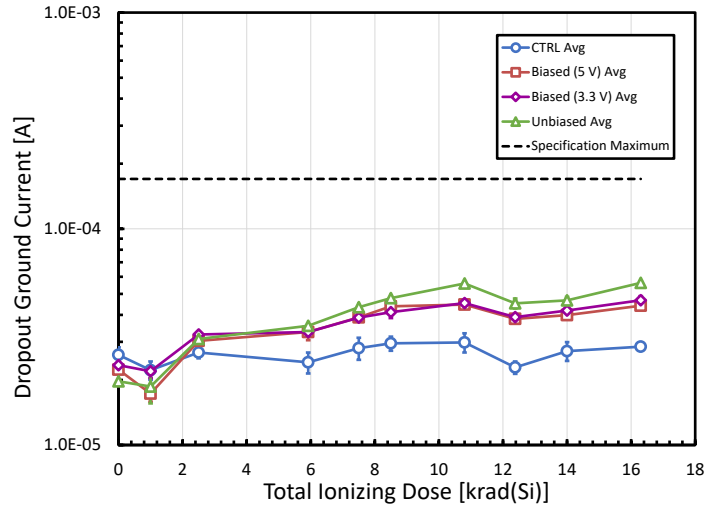


Fig. 30. 3.3-V Current Dropout over dose.

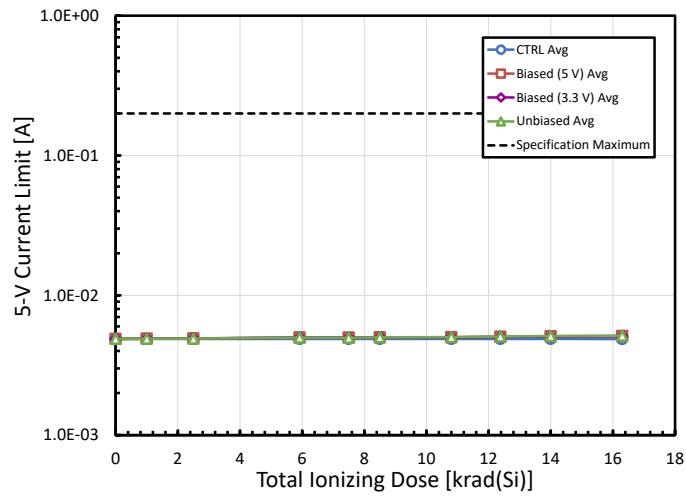


Fig. 31. 5-V Current Limit over dose.

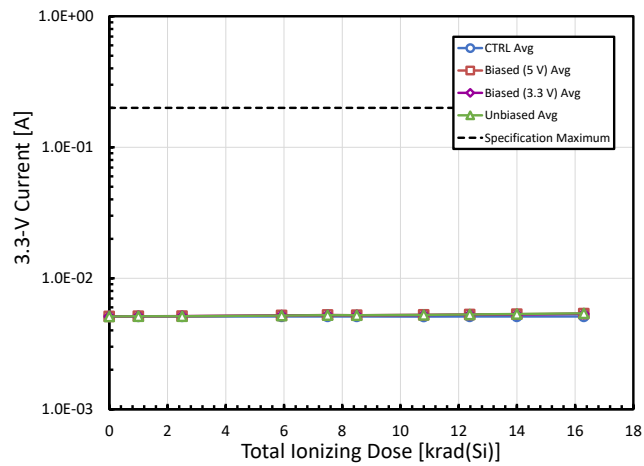


Fig. 32. 3.3-V Current Limit over dose.

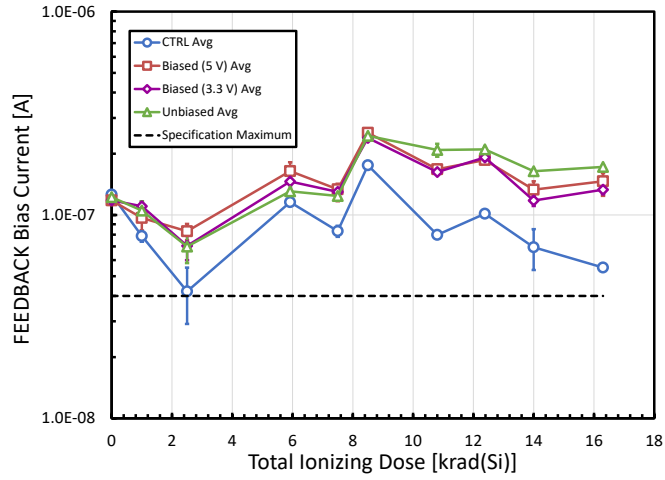


Fig. 33. 5-V Feedback Bias Current over dose.

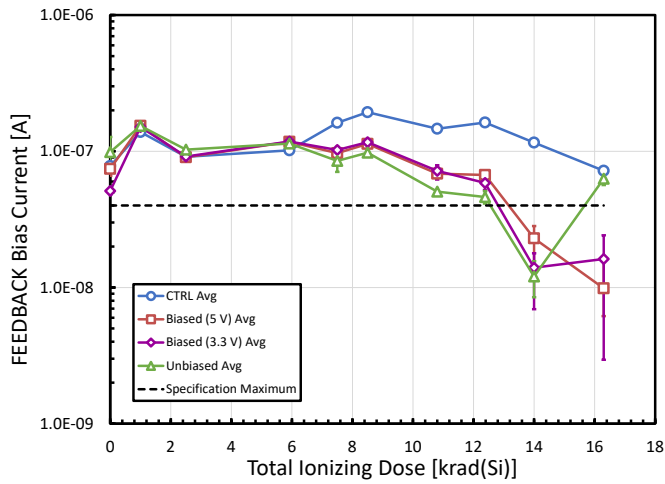


Fig. 34. 3.3-V Feedback Bias Current over dose.

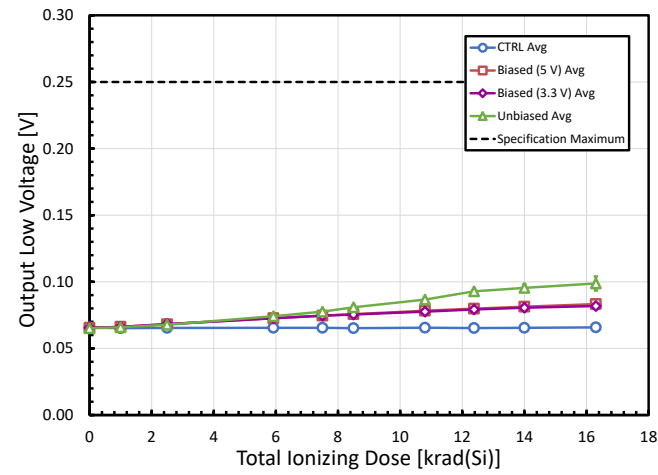


Fig. 35. 5-V Output Low Voltage over dose.

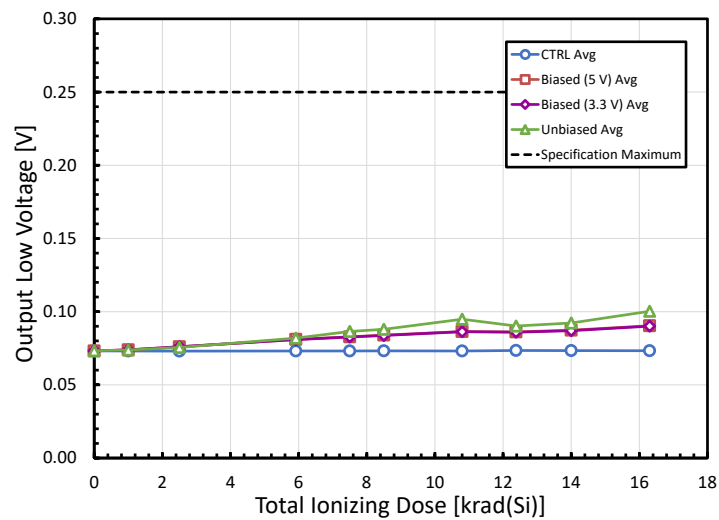


Fig. 36. 3.3-V Output Low Voltage over dose.

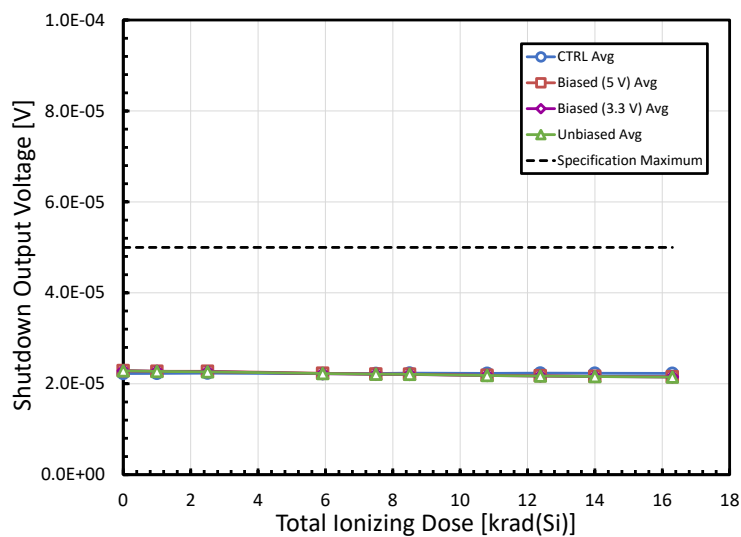


Fig. 37. 5-V Shutdown Output Voltage ($V_{SD} = 2.4$ V) over dose.

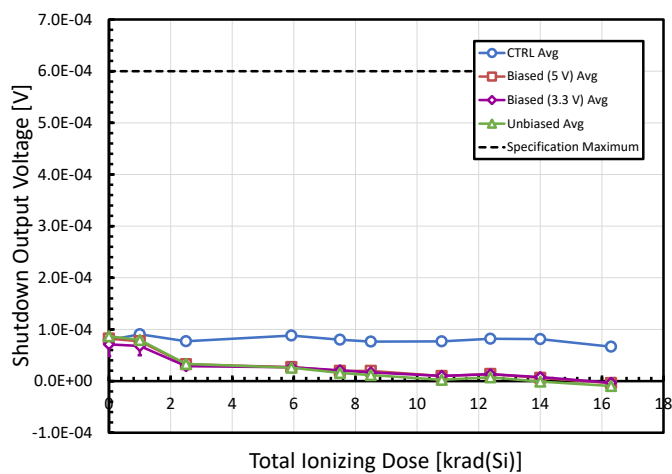


Fig. 38. 5-V Shutdown Output Voltage ($V_{SD} = 30\text{ V}$) over dose.

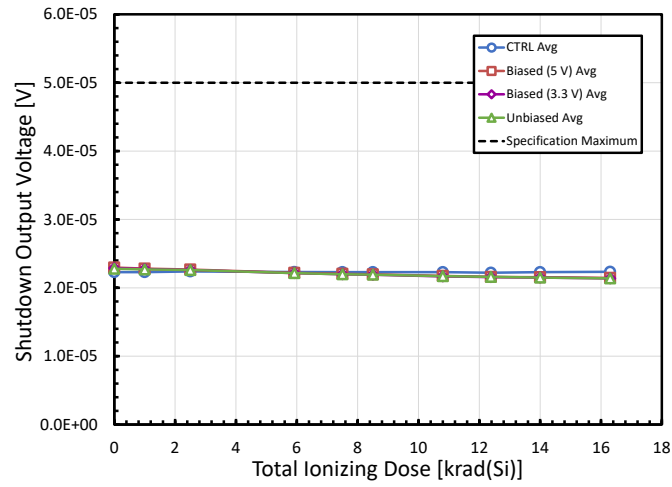


Fig. 39. 3.3-V Shutdown Output Voltage ($V_{SD} = 2.4\text{ V}$) over dose.

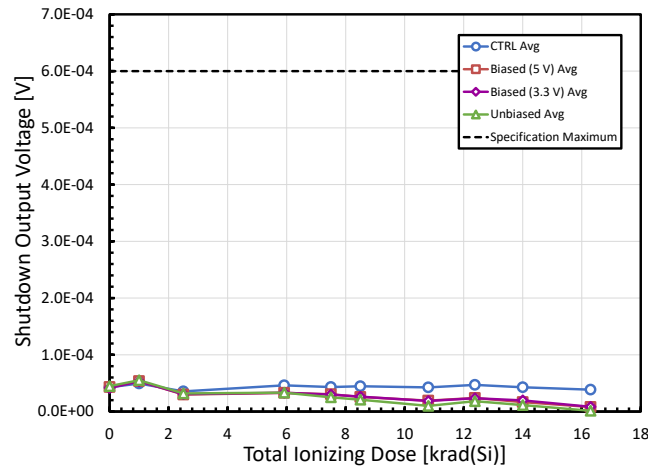


Fig. 40. 3.3-V Shutdown Output Voltage ($V_{SD} = 30\text{ V}$) over dose.

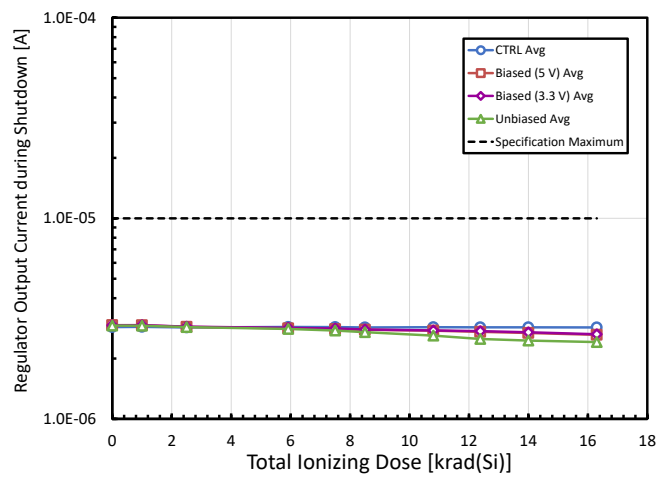


Fig. 41. 5-V Regulator Output Current during Shutdown over dose.

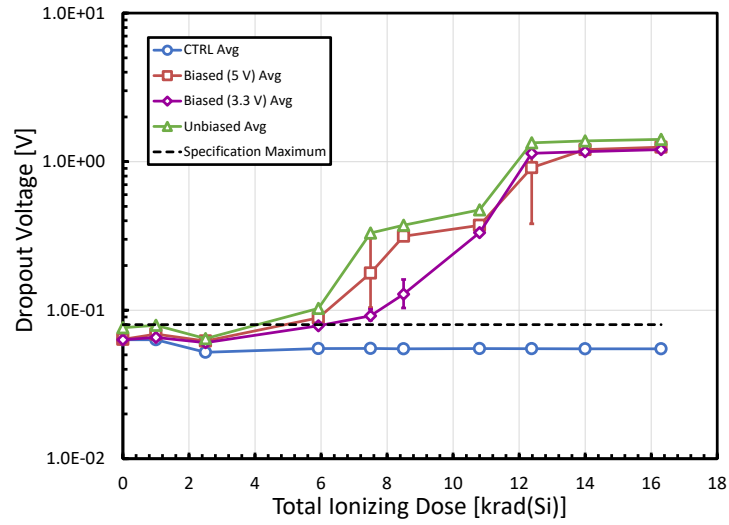


Fig. 42. 5-V Dropout Voltage ($I_L = 100 \text{ uA}$) over dose.

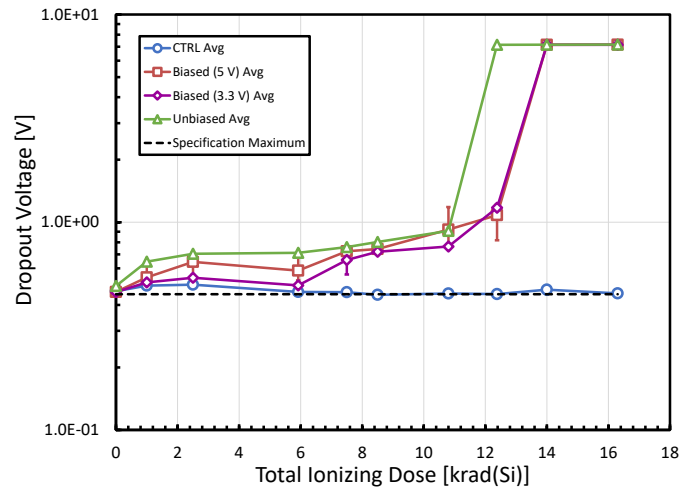


Fig. 43. 5-V Dropout Voltage ($I_L = 100 \text{ mA}$) over dose.

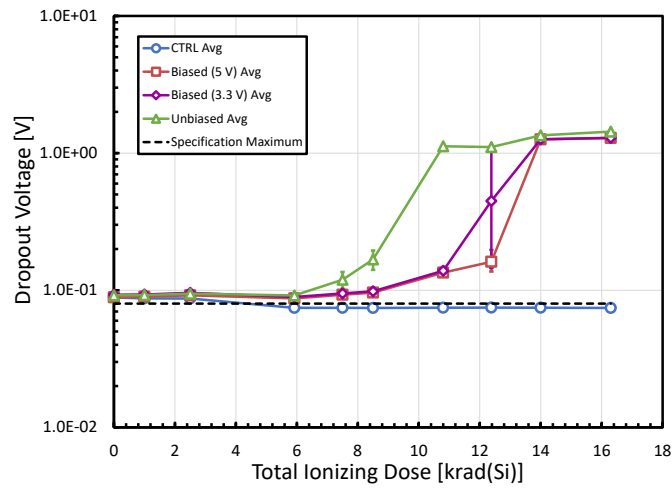


Fig. 44. 3.3-V Dropout Voltage ($I_L = 100 \text{ uA}$) over dose.

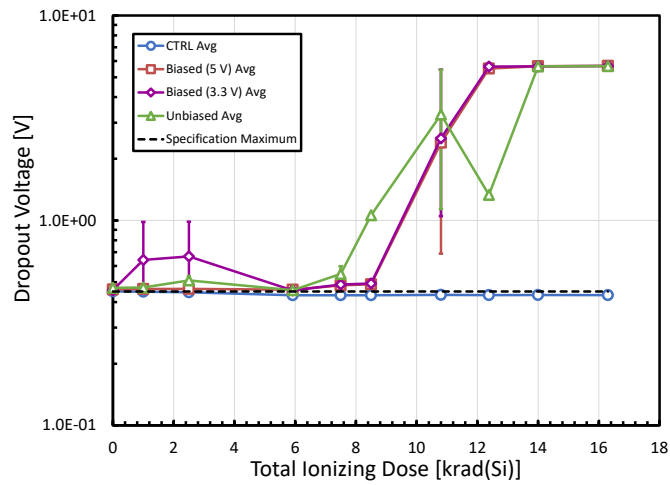


Fig. 45. 3.3-V Dropout Voltage ($I_L = 100$ mA) over dose.

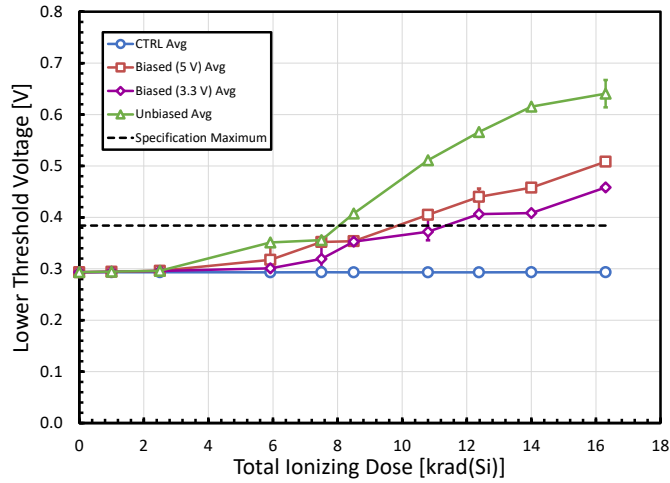


Fig. 46. 5-V Lower Threshold Voltage (Error Low) over dose.

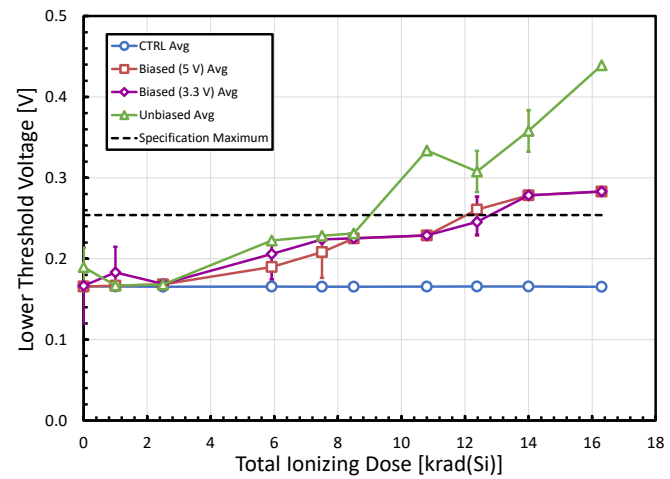


Fig. 47. 3.3-V Lower Threshold Voltage (Error Low) over dose.

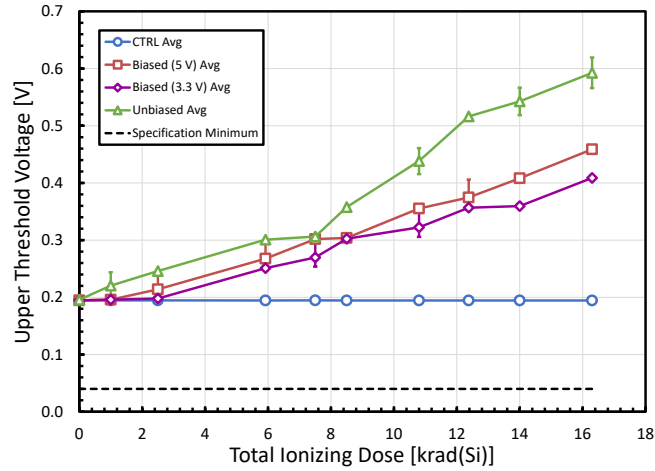


Fig. 48. 5-V Upper Threshold Voltage (Error High) over dose.

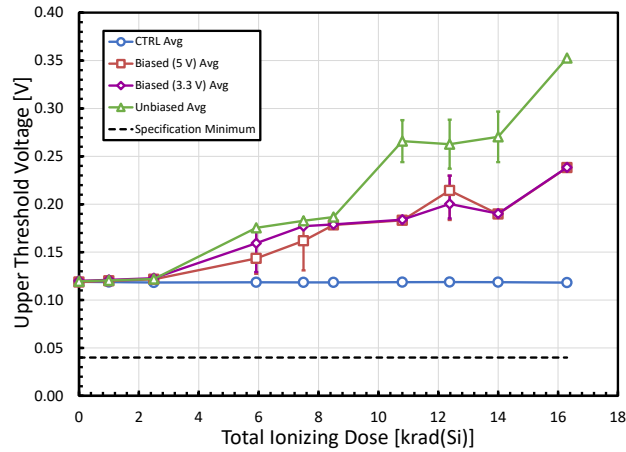


Fig. 49. 3.3-V Upper Threshold Voltage (Error High) over dose.

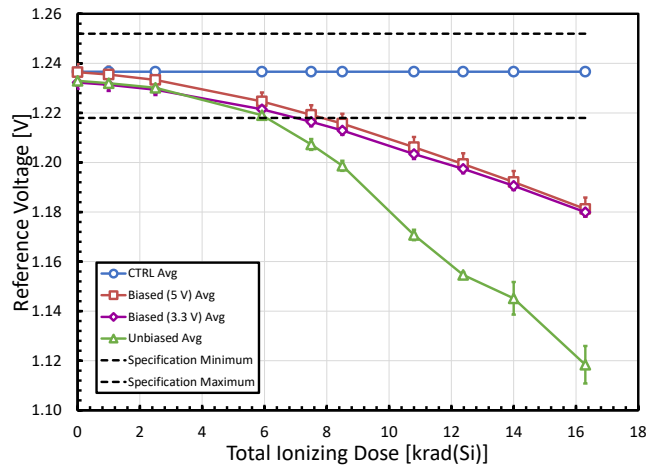


Fig. 50. Reference Voltage ($V_{IN} = 2.3$ V, $I_L = 100$ uA) over dose.

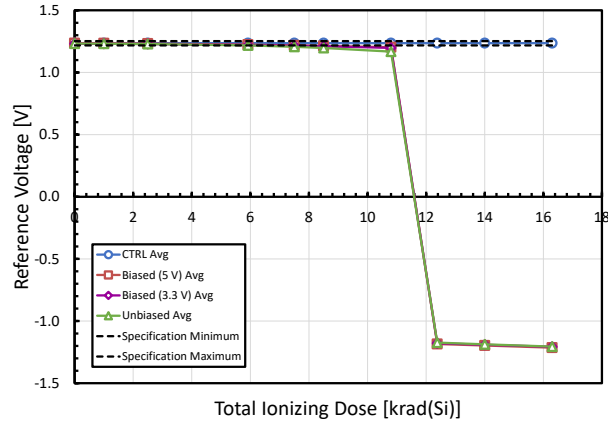


Fig. 51. Reference Voltage ($V_{IN} = 2.3$ V, $I_L = 100$ mA) over dose.

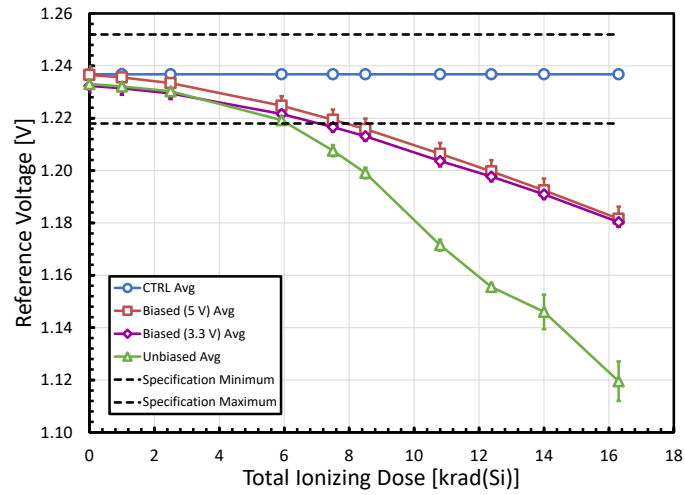


Fig. 52. Reference Voltage ($V_{IN} = 4.3$ V, $I_L = 100$ uA) over dose.

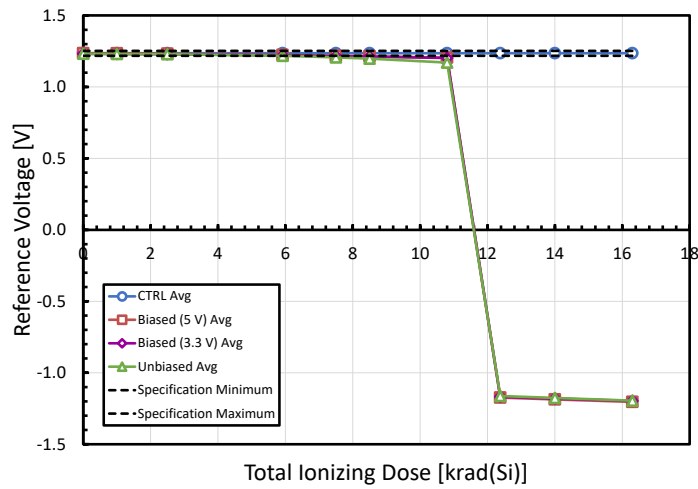


Fig. 53. Reference Voltage ($V_{IN} = 4.3$ V, $I_L = 100$ mA) over dose.

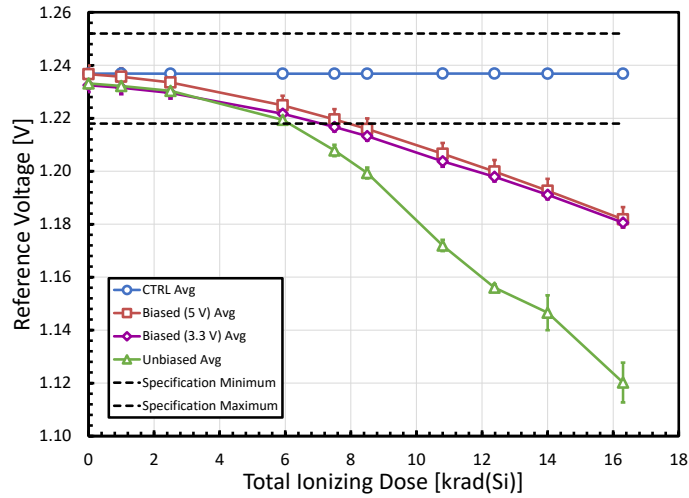


Fig. 54. Reference Voltage ($V_{IN} = 6.3$ V, $I_L = 100$ uA) over dose.

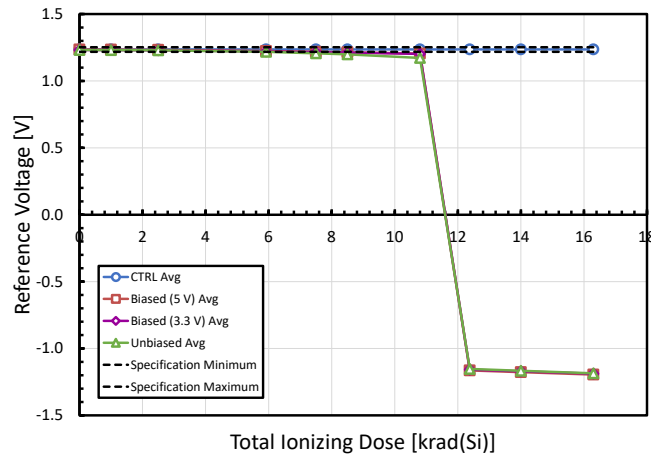


Fig. 55. Reference Voltage ($V_{IN} = 6.3$ V, $I_L = 100$ mA) over dose.

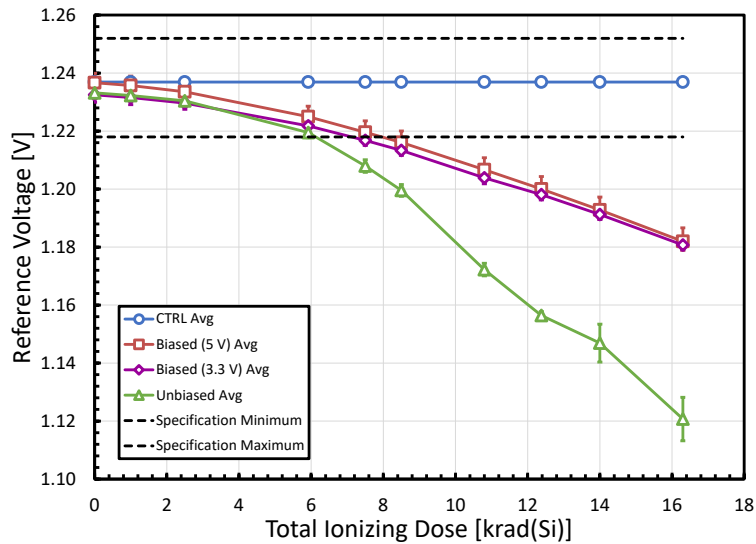


Fig. 56. Reference Voltage ($V_{IN} = 8.3$ V, $I_L = 100$ uA) over dose.

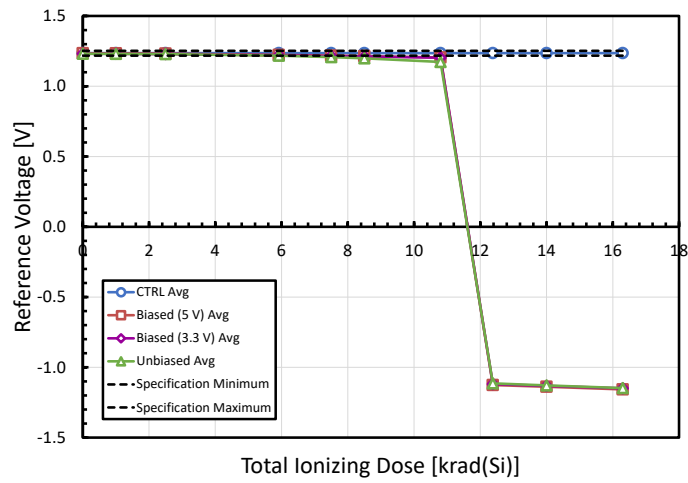


Fig. 57. Reference Voltage ($V_{IN} = 8.3 \text{ V}$, $I_L = 100 \text{ mA}$) over dose.

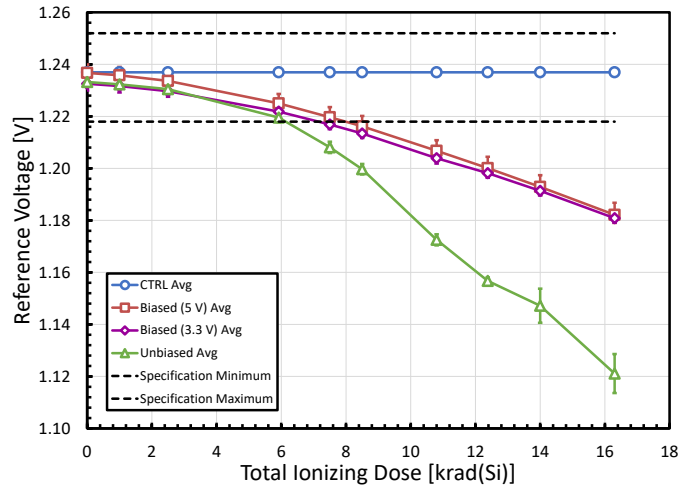


Fig. 58. Reference Voltage ($V_{IN} = 10.3 \text{ V}$, $I_L = 100 \text{ uA}$) over dose.

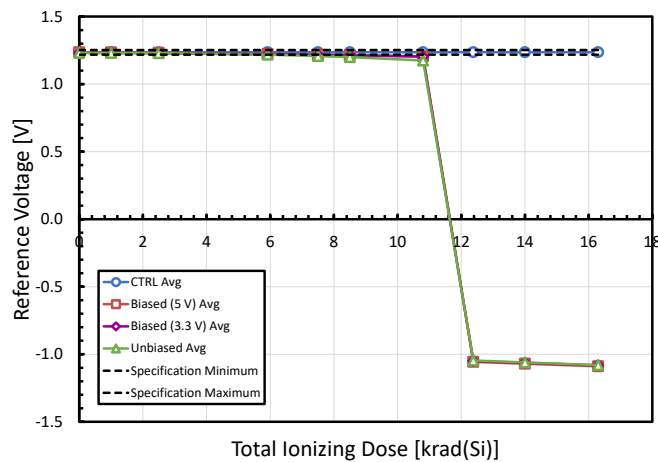


Fig. 59. Reference Voltage ($V_{IN} = 10.3 \text{ V}$, $I_L = 100 \text{ mA}$) over dose.

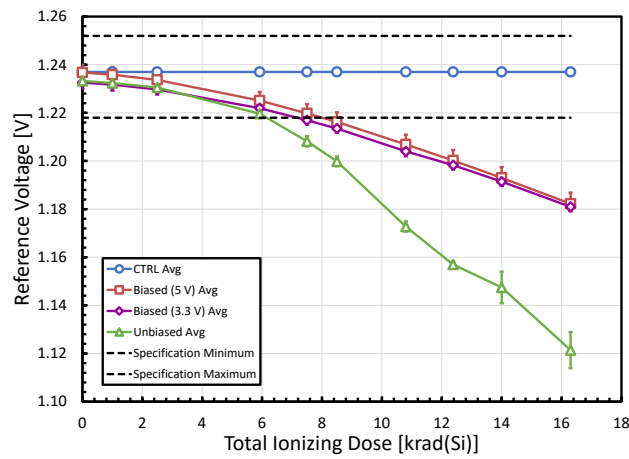


Fig. 60. Reference Voltage ($V_{IN} = 12.3$ V, $I_L = 100$ uA) over dose.

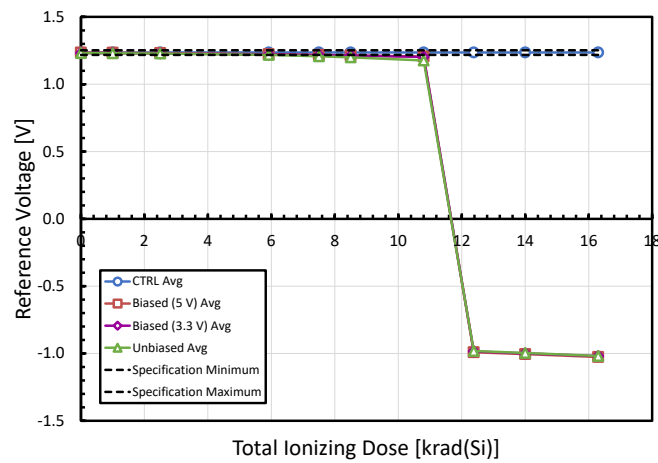


Fig. 61. Reference Voltage ($V_{IN} = 12.3$ V, $I_L = 100$ mA) over dose.

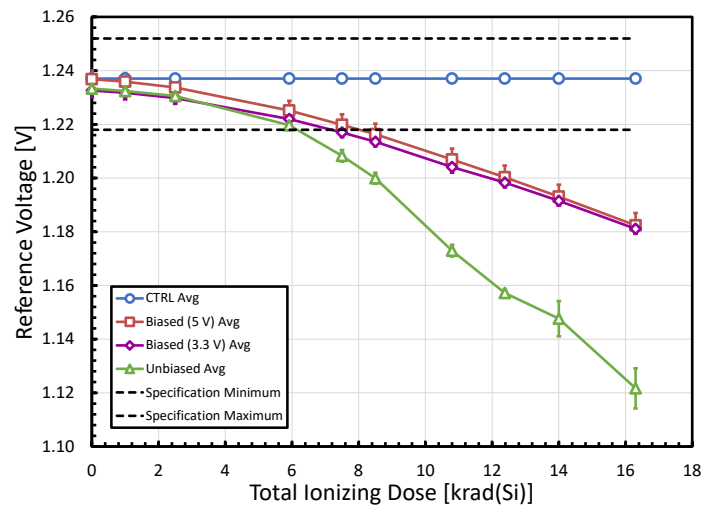


Fig. 62. Reference Voltage ($V_{IN} = 14.3$ V, $I_L = 100$ uA) over dose.

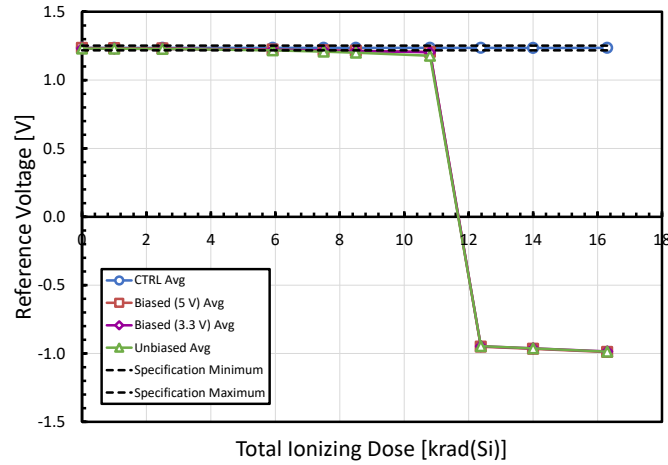


Fig. 63. Reference Voltage ($V_{IN} = 14.3$ V, $I_L = 100$ mA) over dose.

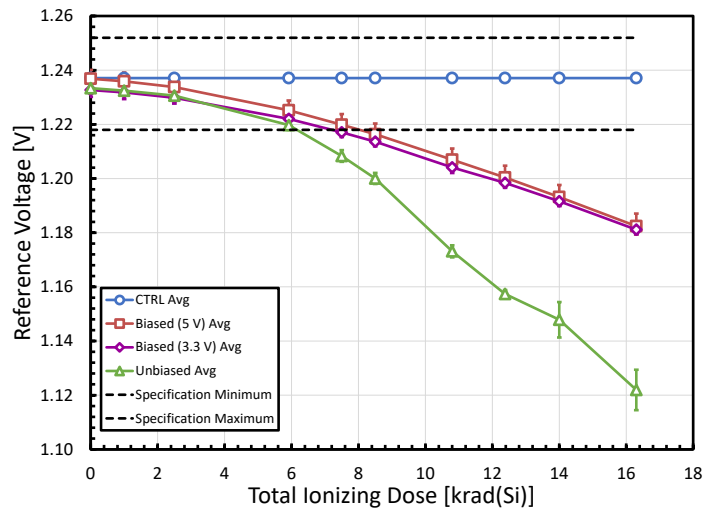


Fig. 64. Reference Voltage ($V_{IN} = 16.3$ V, $I_L = 100$ uA) over dose.

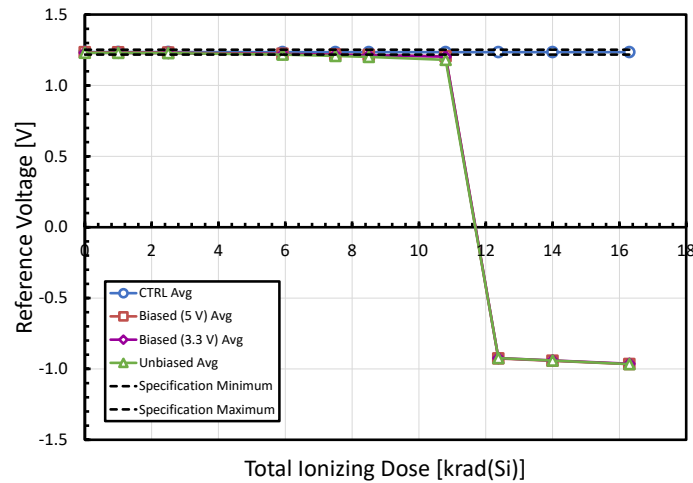


Fig. 65. Reference Voltage ($V_{IN} = 16.3$ V, $I_L = 100$ mA) over dose.

8. CONCLUSIONS

Several parameters went out of specification before the final dose step at 16.3 krad(Si).

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) LP2951JAN Series of Adjustable Micropower Voltage Regulators, Texas Instruments, April 2013.

