ISL70003SEH

Neutron Test Report

TR026
Rev 0.00
March 8, 2016

Introduction

This report summarizes results of 1MeV equivalent neutron testing of the ISL70003SEH integrated FET point-of-load regulator. The test was conducted in order to determine the sensitivity of the part to Displacement Damage (DD) caused by neutron or proton environments. Neutron fluences ranged from $2x10^{12}$ n/cm2 to $1x10^{14}$ n/cm^2. This project was carried out in collaboration with VPT, Inc. (Blacksburg, VA) and their support is gratefully acknowledged.

Reference Documents

For more information about the ISL70003SEH, refer to the following documentation.

- ISL70003SEH datasheet
- Standard Microcircuit Drawing (SMD): 5962-14203
- MIL-STD-883 test method 1017
- AN1913 “Single Event Effects Testing of the ISL70003SEH, a 3V to 13.2V, 6A Synchronous Buck Regulator”

Part Description

The ISL70003SEH is a radiation hardened synchronous buck regulator capable of operating over an input voltage range of 3.0V to 13.2V. With integrated MOSFETs, the part provides an efficient single chip power solution that is externally adjustable from 0.6V to ~90% of the input voltage. Continuous output load current capability is 6A for TJ ≤ +125°C and 3A for TJ ≤ +150°C. The ISL70003SEH uses voltage mode control architecture with feed-forward and switches at pin-selected fixed frequencies of 500kHz or 300kHz. Loop compensation is externally adjustable to allow for an optimum balance between stability and output dynamic performance. The on-chip synchronous power MOSFET switches are optimized for efficiency and thermal performance. The chip features two logic-level disable inputs that can be used to inhibit pulses on the phase (LXx) pins in order to maximize efficiency as a function of load current.

The ISL70003SEH supports DDR applications and contains a buffer amplifier for generating the V_{REF} voltage required by that protocol. Typical ISL70003SEH applications include FPGA, CPLD and DSP power management, CPU core and I/O supply and DDR memory power management in high-density distributed power systems for space applications.

The ISL70003SEH is hardened to achieve a Total Dose (TID) rating of 100krad(Si) at both high (50-300rad(Si)/s) and low (≤0.01rad(Si)/s) dose rates as specified in MIL-STD-883 test method 1019. The part is acceptance tested on a wafer-by-wafer basis at low dose rate to 50krad(Si) and at high dose rate to 100krad(Si), as indicated by the '-EH' suffix in the part number.

The ISL70003SEH is also SEE rated to a Linear Energy Transfer (LET) value of 86.4 MeV.cm^2/mg. Single-Event Transients (SET) are well known to be a major issue in power management parts driving voltage-sensitive loads, and the part provides superior performance in this environment; refer to Intersil application note AN1913 for further details. Additional SET hardening is achieved by specifying or restricting the values of certain external components.

The ISL70003SEH is implemented in a submicron junction-isolated BiCMOS process optimized for power management applications, with 0.6µm minimum ground rules and three layers of interconnect. The process is in volume production under MIL-PRF-38535 certification and is used for a wide range of commercial power management devices.

Specifications for radiation hardened QML devices are controlled by the Defense Logistics Agency (DLA) in Columbus, OH. The SMD is the controlling document and must be cited when ordering.

Block Diagram

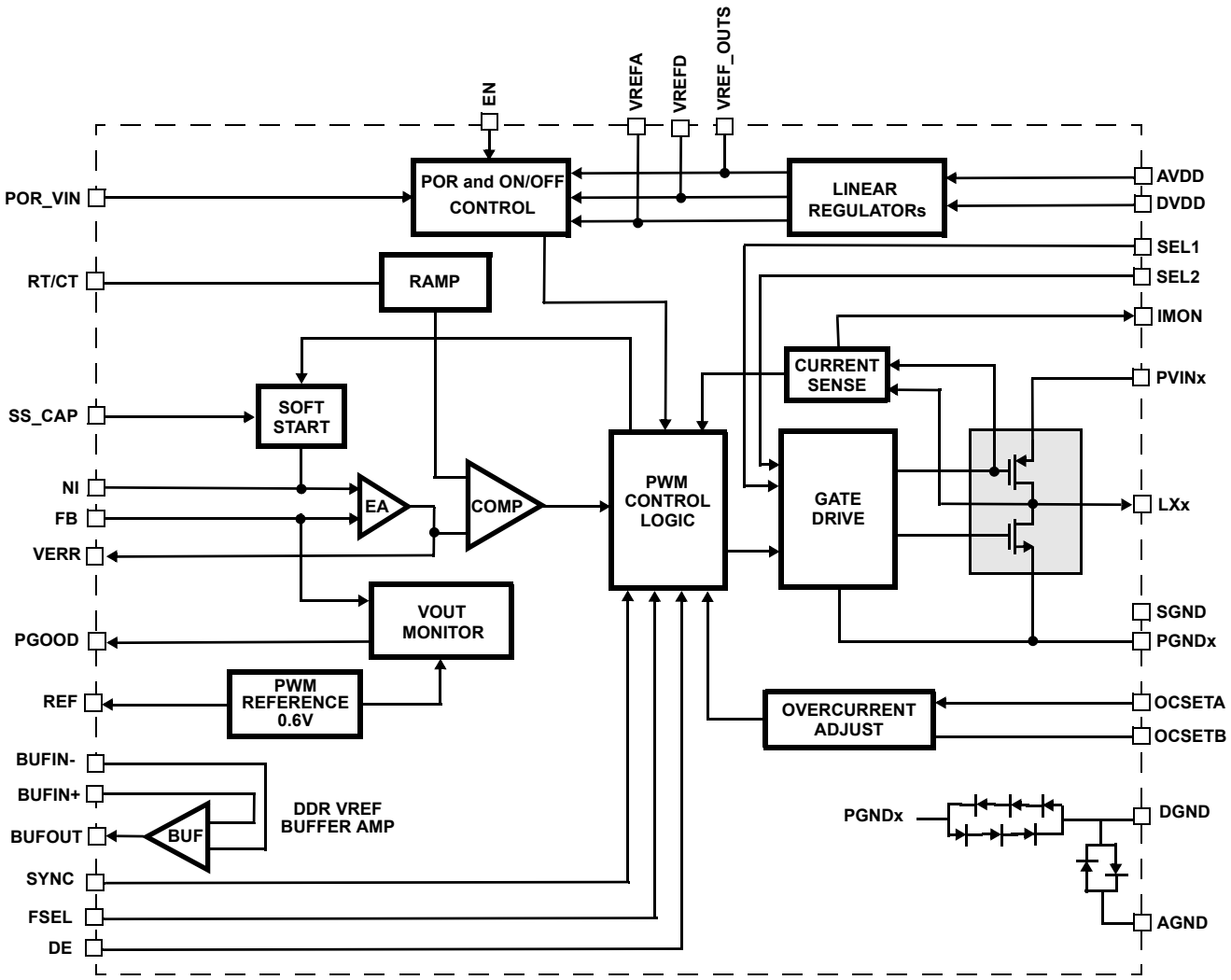

FIGURE 1. BLOCK DIAGRAM

Test Description

Irradiation Facility

Neutron irradiation was performed by the VPT team at the University of Massachusetts Lowell Fast Neutron Irradiation (FNI) facility, which provides a controlled 1MeV equivalent neutron flux. Parts were tested in an unbiased configuration with all leads shorted together in accordance with TM 1017 of MIL-STD-883. As neutron irradiation activates many of the heavier elements found in a packaged integrated circuit, the parts exposed at the higher neutron levels required (as expected) some 'cooldown' time before being shipped back to Intersil (Palm Bay, FL) for electrical testing.

Test Fixturing

No formal irradiation test fixturing is involved, as these DD tests are 'bag tests' in the sense that the parts are irradiated with all leads shorted together.

Characterization Equipment

Electrical testing was performed before and after irradiation using the Intersil production Automated Test Equipment (ATE). All electrical testing was performed at room temperature.

Experimental Matrix

Testing proceeded in general accordance with the guidelines of MIL-STD-883 TM 1017. The experimental matrix consisted of 5 samples irradiated at 2×10^{12} n/cm^2, 5 irradiated at 1×10^{13} n/cm^2, 5 irradiated at 3×10^{13} n/cm^2 and 5 irradiated at 1×10^{14} n/cm^2. Two control units were used.

The ISL70003SEH samples were drawn from Lot 3XKFBC. Samples were packaged in the standard hermetic 64 Ld Ceramic Quad Flatpack (CQFP) production package, code RKV. Samples were processed through burnin before irradiation and were screened to the SMD limits at room, low and high temperatures before the start of neutron testing.

Results

Test Results

Neutron testing of the ISL70003SEH is complete and the results are reported in the balance of this report. It should be carefully realized when interpreting the data that each neutron irradiation was performed on a different five-unit sample; this is not total dose testing, where the damage is cumulative.

Attributes Data

TABLE 1. ATTRIBUTES DATA

PART	FLUENCE, n/cm^2	SAMPLE SIZE	PASS (Note 1)	FAIL
ISL70003SEH	2×10^{12}	5	5	0
ISL70003SEH	1×10^{13}	5	5	0
ISL70003SEH	3×10^{13}	5	0	5
ISL70003SEH	1×10^{14}	5	0	5

NOTE:

1. 'Pass' indicates a sample that passes all SMD limits.

Variables Data

The plots in Figures 2 through 29 show data plots for key parameters before and after irradiation to each level. The plots show the median of each parameter as a function of neutron irradiation. We chose to plot the median because of the small sample sizes (five per cell) involved. We also show the applicable electrical limits taken from the SMD; it should be carefully noted that these limits are provided for guidance only as the ISL70003SEH is not specified for the neutron environment.

All samples passed the post-irradiation SMD limits after 2×10^{12} and 1×10^{13} n/cm^2 but failed the SMD post-irradiation limits after 3×10^{13} and 1×10^{14} n/cm^2.

Variables Data Plots

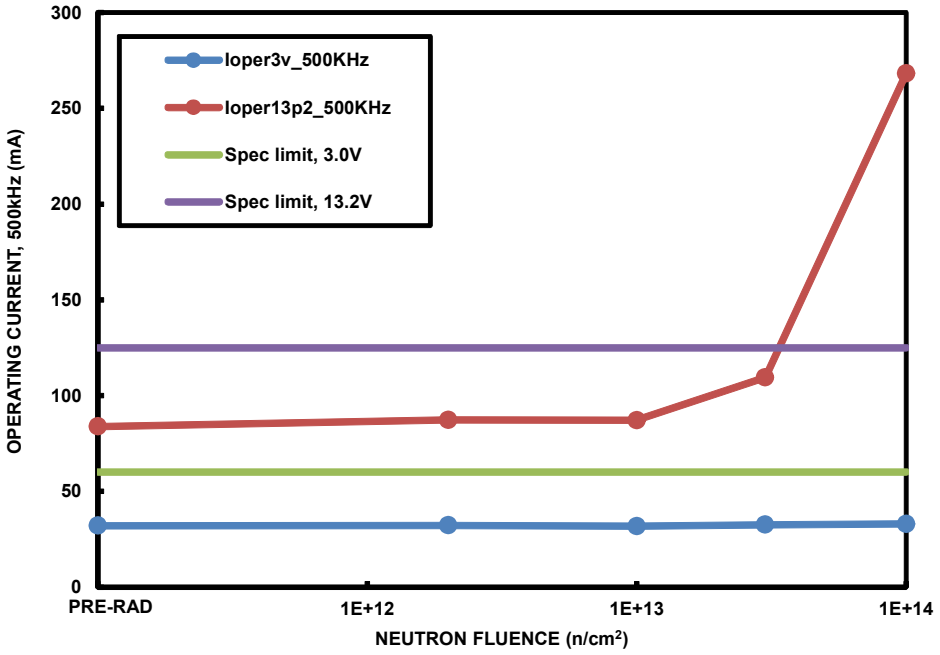

FIGURE 2. ISL70003SEH operating current at 500kHz, 3V (blue) and 13.2V (red) input voltage cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2×10^{12} n/cm^2 (5 samples), 1×10^{13} n/cm^2 (5 samples), 3×10^{13} n/cm^2 (5 samples) and 1×10^{14} n/cm^2 (5 samples). The SMD limits are 60.0mA maximum (3V case) and 125.0mA maximum (13.2V case).

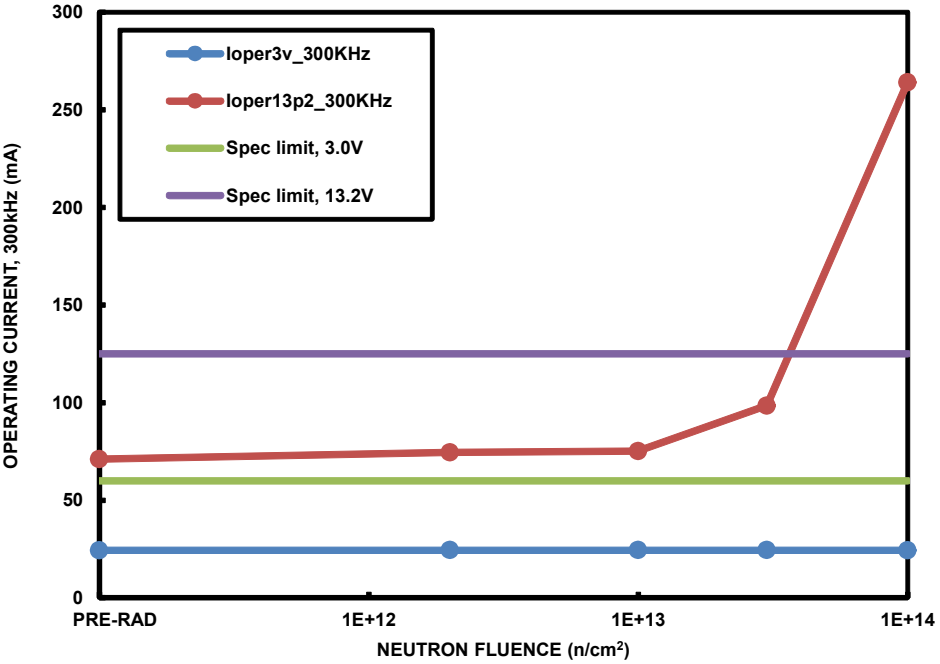

FIGURE 3. ISL70003SEH operating current at 300kHz, 3V (blue) and 13.2V (red) input voltage cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2×10^{12} n/cm^2 (5 samples), 1×10^{13} n/cm^2 (5 samples), 3×10^{13} n/cm^2 (5 samples) and 1×10^{14} n/cm^2 (5 samples). The SMD limits are 60.0mA maximum (3V case) and 125.0mA maximum (13.2V case).

Variables Data Plots (Continued)

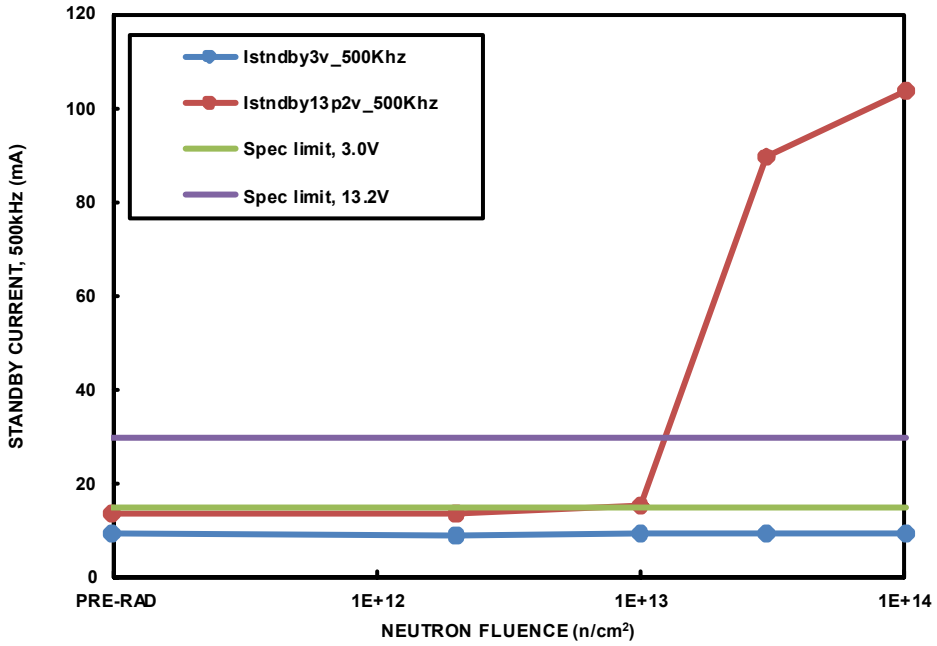

FIGURE 4. ISL70003SEH standby current at 500kHz, 3V (blue) and 13.2V (red) cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 15.0mA maximum (3V case) and 30.0mA maximum (13.2V case).

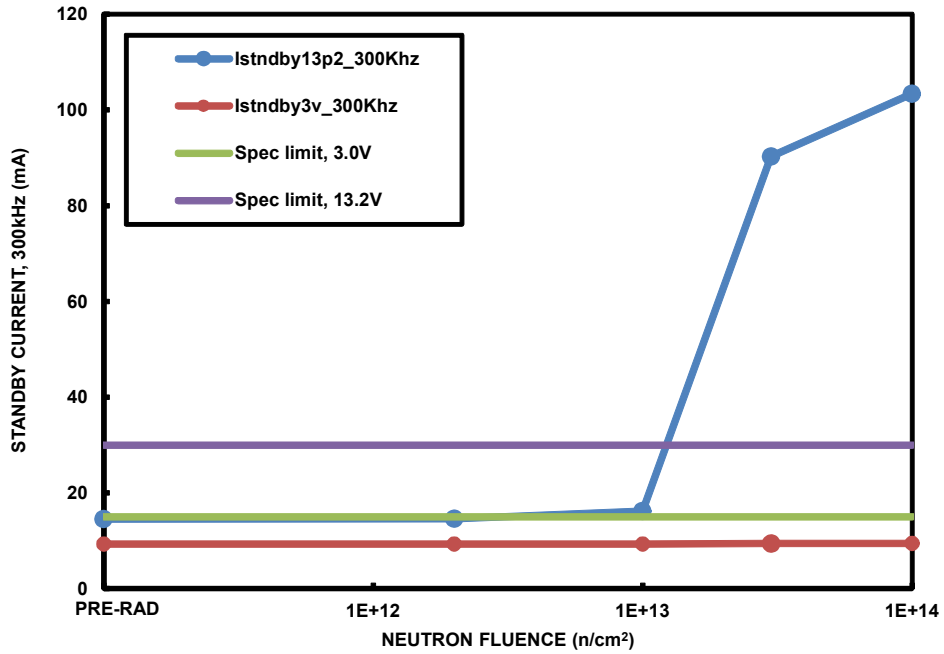

FIGURE 5. ISL70003SEH standby current at 300kHz, 3V (red) and 13.2V (blue) cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 15.0mA maximum (3V case) and 30.0mA maximum (13.2V case).

Variables Data Plots (Continued)

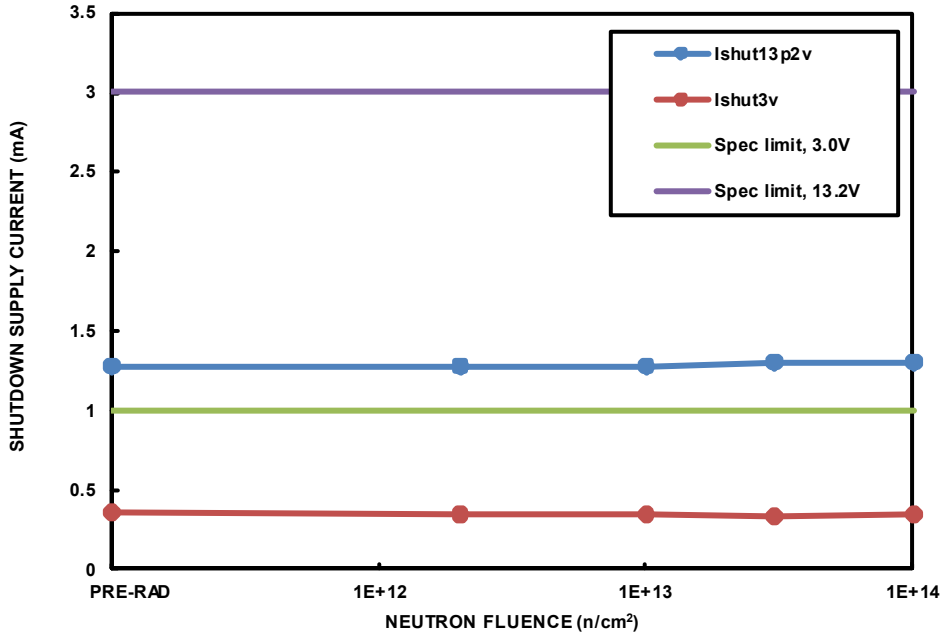

FIGURE 6. ISL70003SEH shutdown ('quiescent') supply current, 3V (red) and 13.2V (blue) cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 1 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 2 x 10^{14} n/cm^2 (5 samples). The SMD limits are 1.0mA maximum (3V case) and 3.0mA maximum (13.2V case).

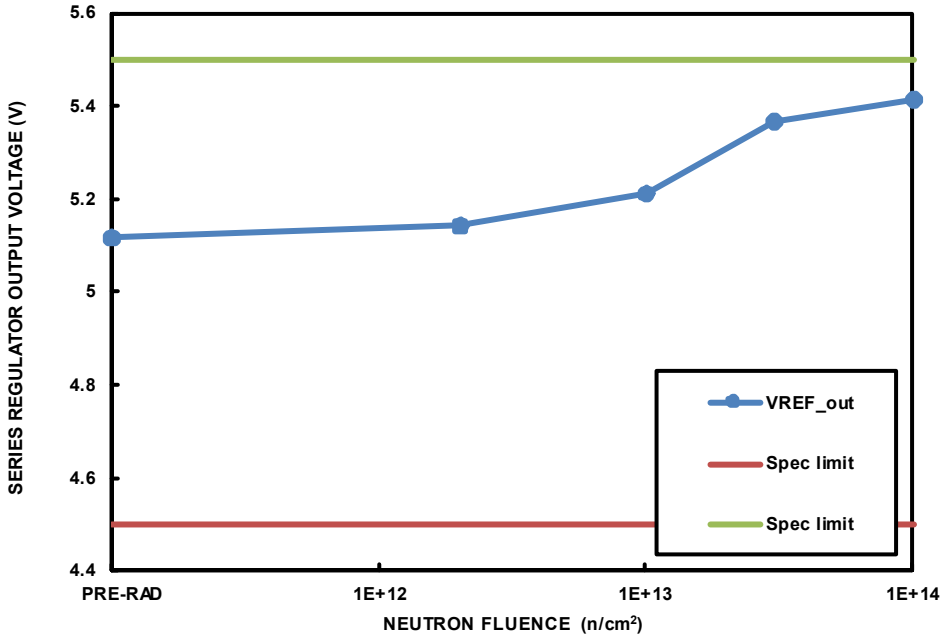

FIGURE 7. ISL70003SEH series regulator output voltage, 13.2V input (blue), as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 4.5V to 5.5V.

Variables Data Plots (Continued)

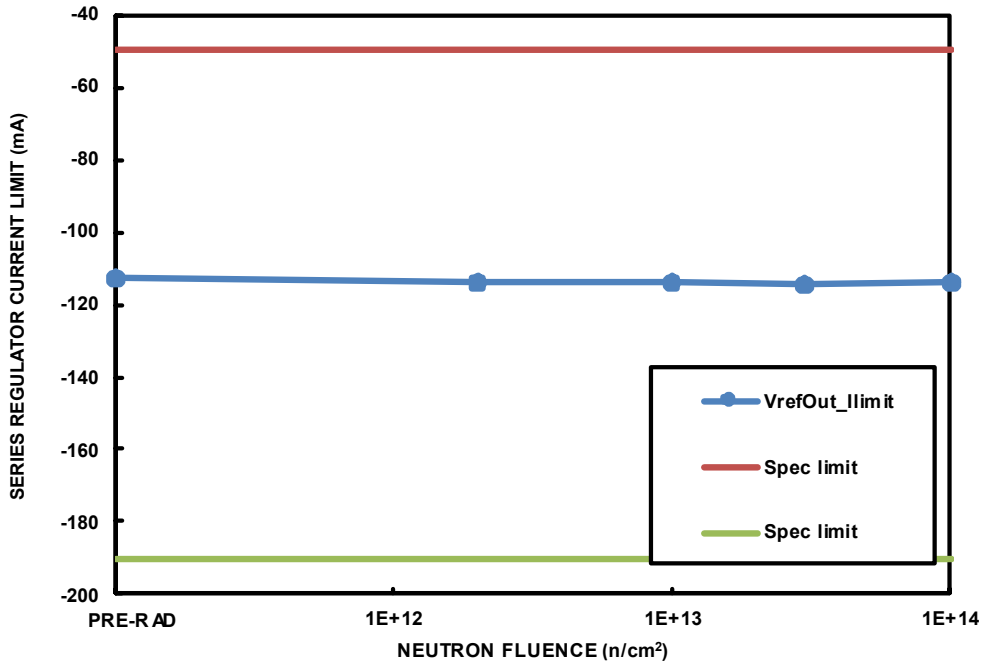

FIGURE 8. ISL70003SEH on-chip series regulator current limit (blue) as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are -50.0mA to -190.0mA.

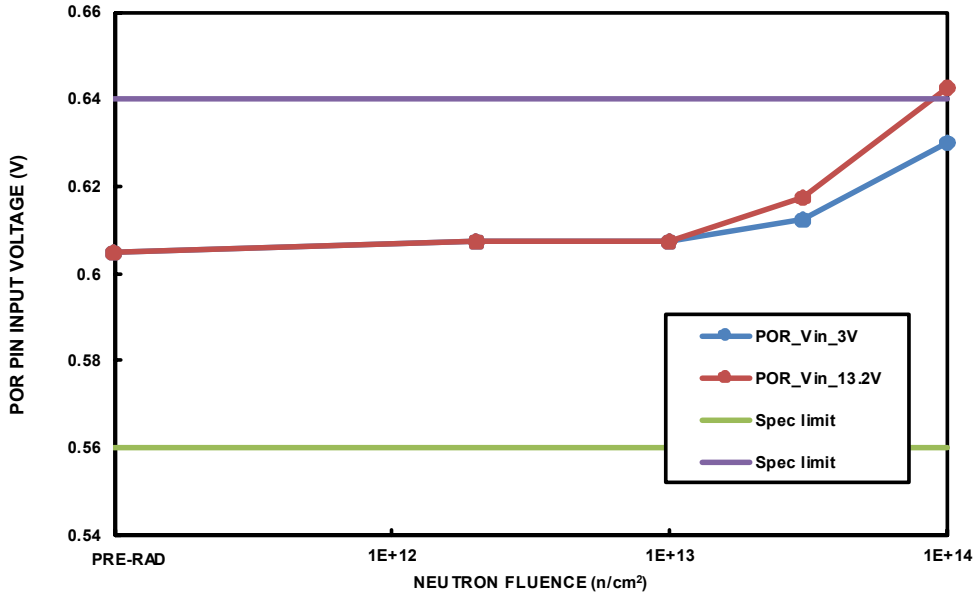

FIGURE 9. ISL70003SEH POR input pin voltage, 3V (blue) and 13.3V (red) cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 0.56V to 0.64V.

Variables Data Plots (Continued)

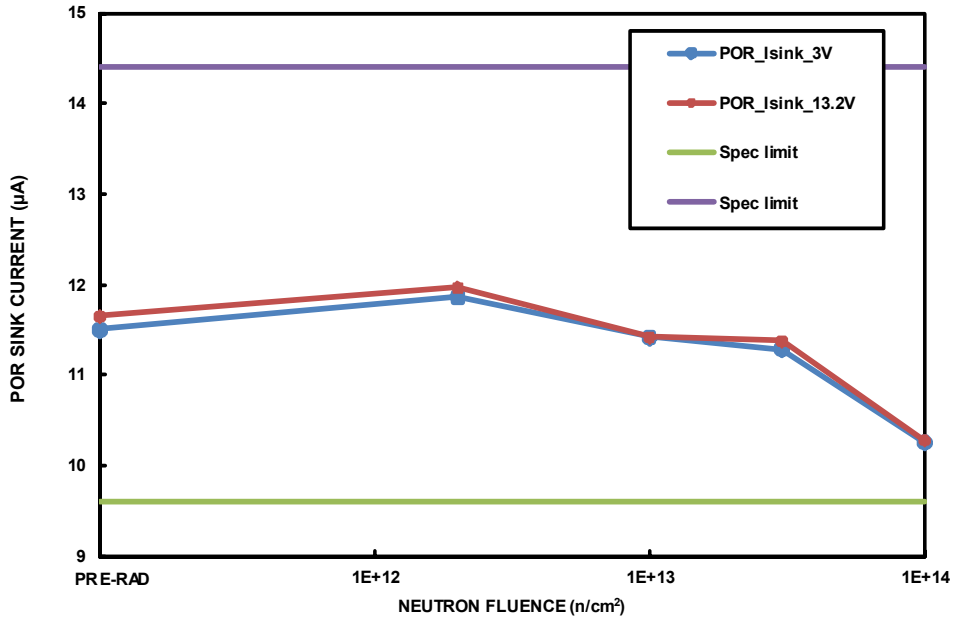

FIGURE 10. ISL70003SEH power on reset (POR) sink current, 3V (blue) and 13.3V (red) cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 9.6mA to 14.4mA.

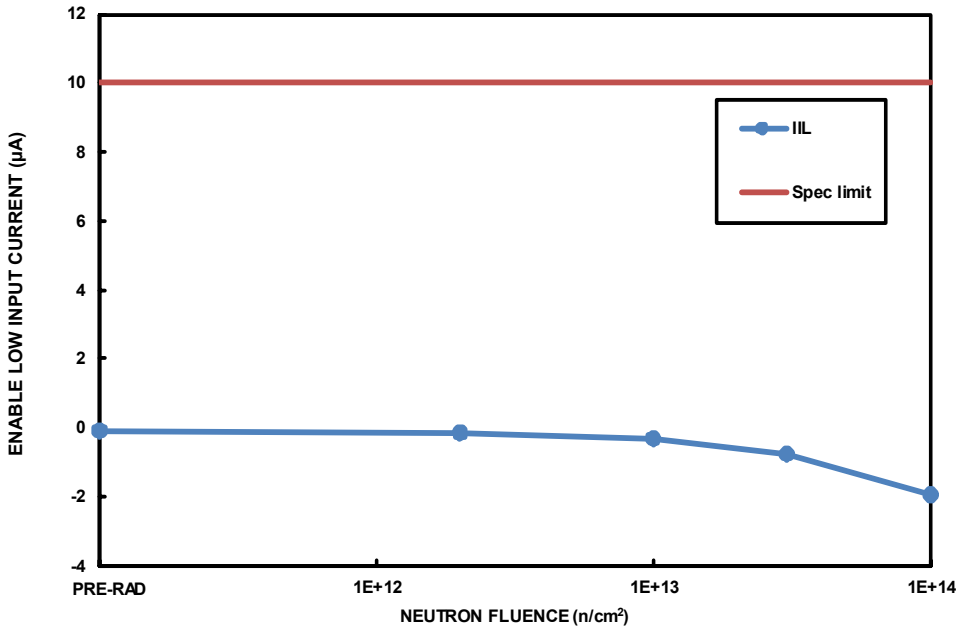

FIGURE 11. ISL70003SEH enable low input current (blue) as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limit is +10.0µA maximum.

Variables Data Plots (Continued)

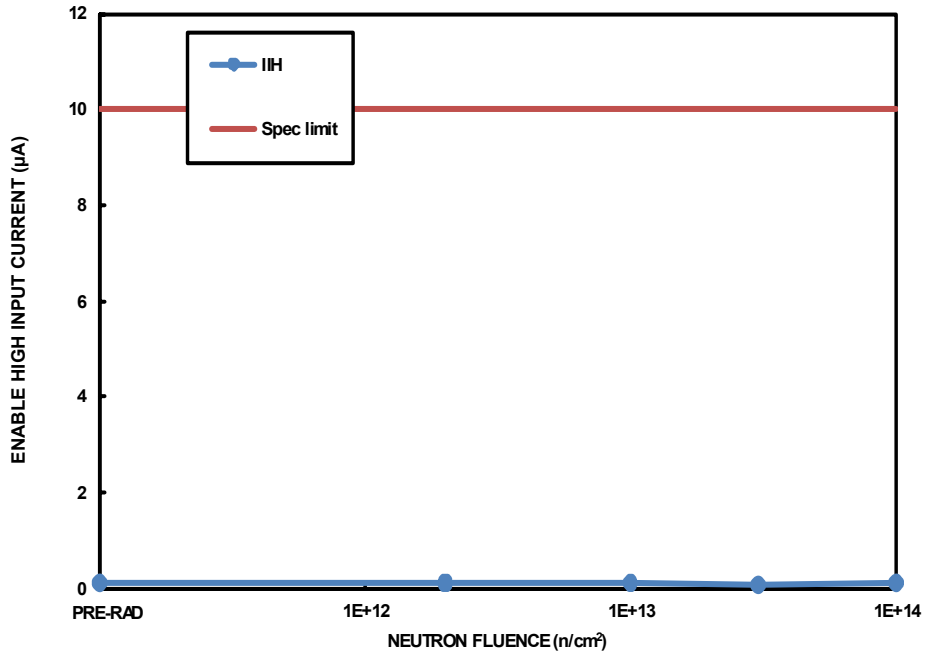

FIGURE 12. ISL70003SEH enable high input current (blue) as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limit is +10.0µA maximum.

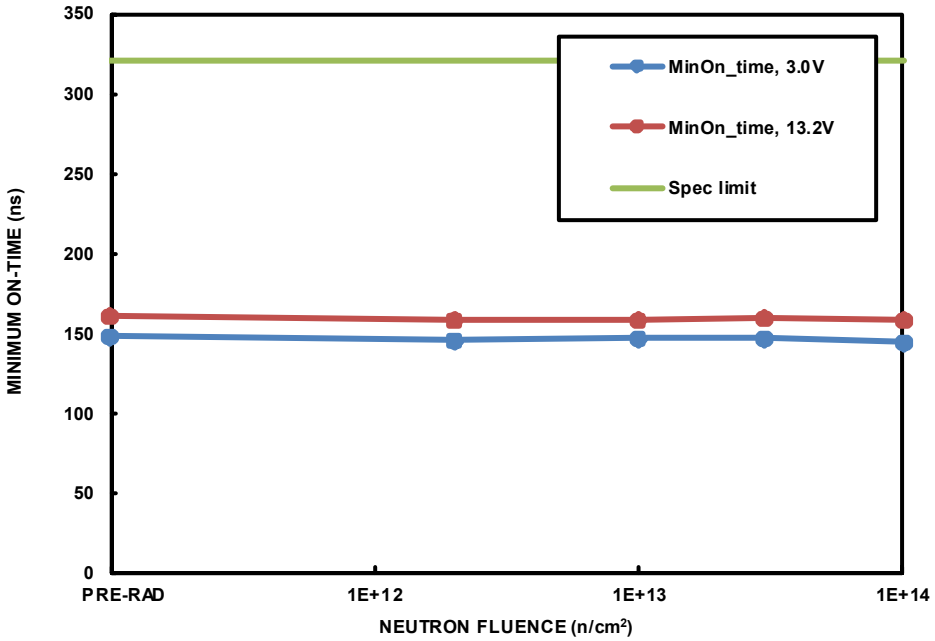

FIGURE 13. ISL70003SEH minimum on-time, 3V (blue) and 13.2V (red) cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limit is 320.0ns maximum.

Variables Data Plots (Continued)

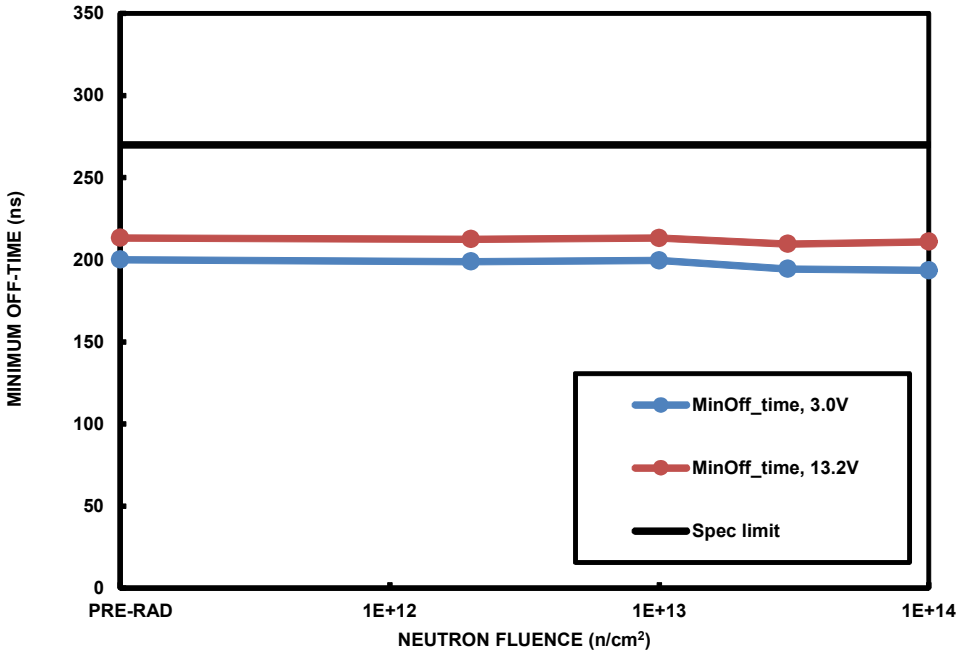

FIGURE 14. ISL70003SEH minimum off-time, 3V (blue) and 13.2V (red) cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limit is 270.0ns maximum.

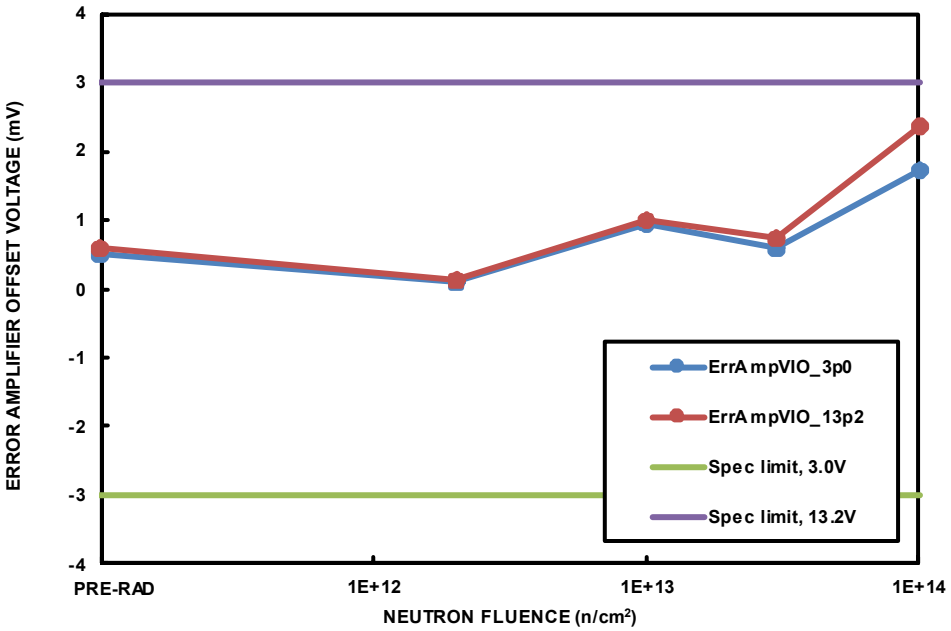

FIGURE 15. ISL70003SEH error amplifier input offset voltage, 3V (blue) and 13.2V (red) cases as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are -3.0mV to 3.0mV.

Variables Data Plots (Continued)

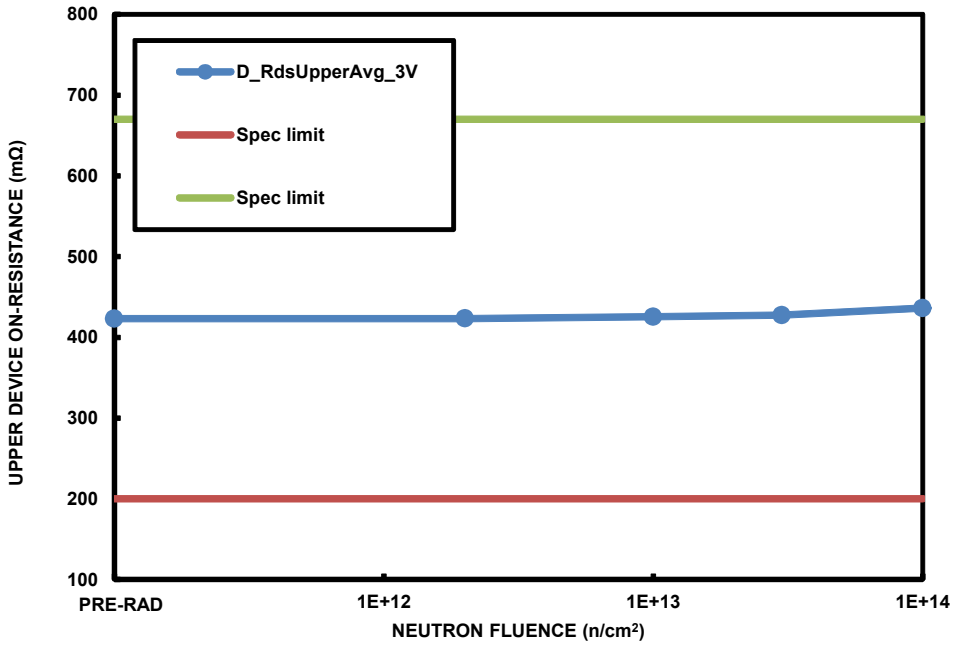

FIGURE 16. ISL70003SEH average upper device ON-resistance at 3V in (blue), ten power blocks, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 170.0mΩ to 700.0mΩ.

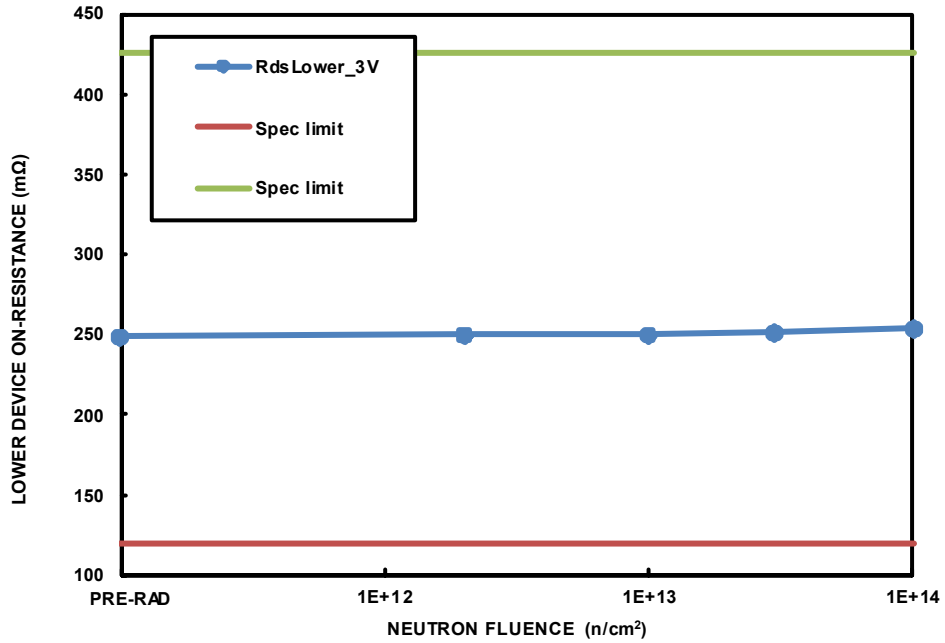

FIGURE 17. ISL70003SEH average lower device ON-resistance at 3V in (blue), ten power blocks, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 90.0mΩ to 455.0mΩ.

Variables Data Plots (Continued)

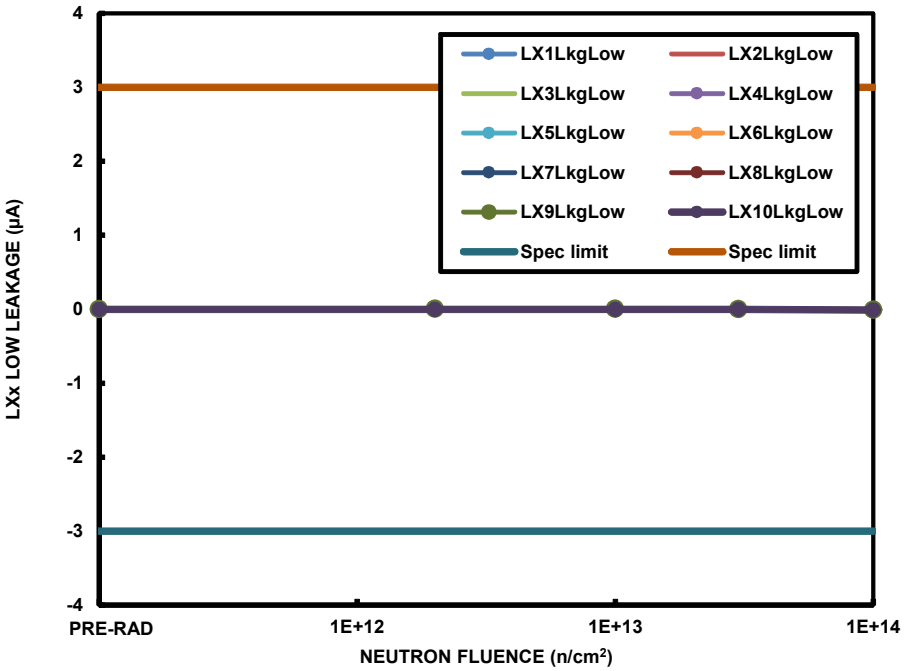

FIGURE 18. ISL70003SEH LXx low leakage current, each of ten power blocks, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are -3.0µA to +3.0µA.

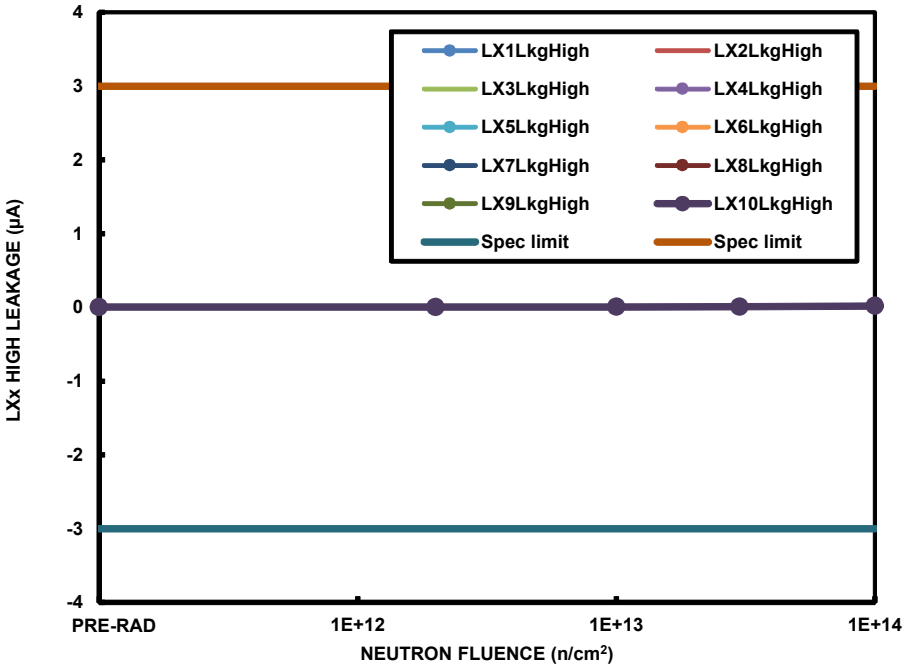

FIGURE 19. ISL70003SEH LXx high leakage current, each of ten power blocks, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are -3.0µA to +3.0µA.

Variables Data Plots (Continued)

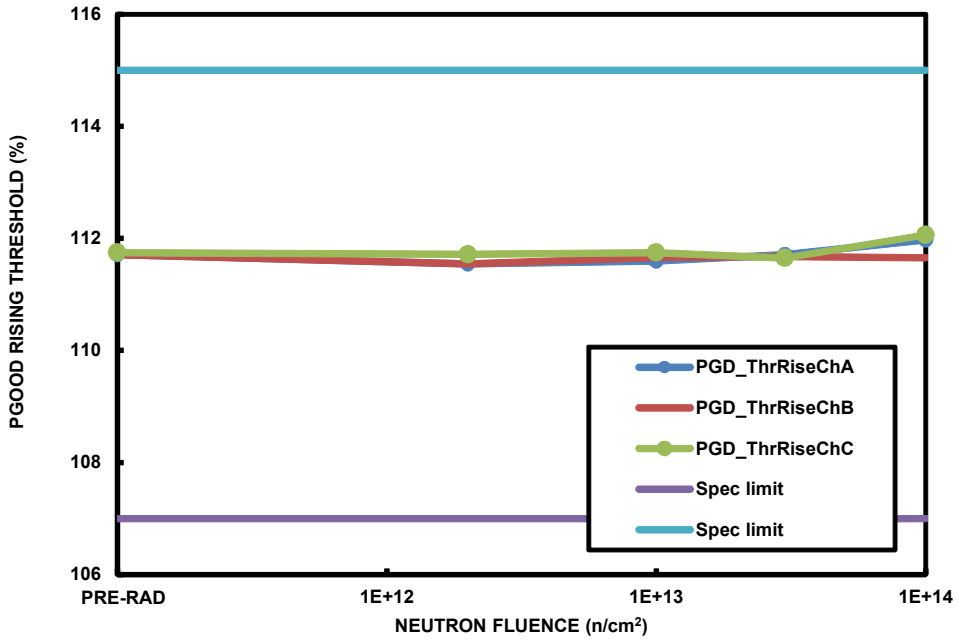

FIGURE 20. ISL70003SEH PGOOD rising threshold, channels A (blue), B (red) and C (green), as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 107% to 118%.

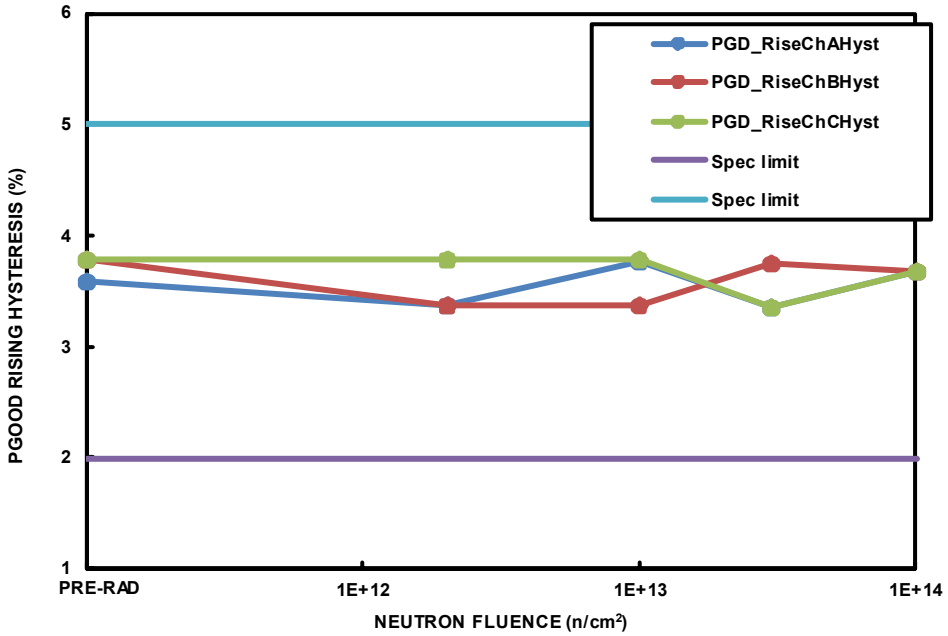

FIGURE 21. ISL70003SEH PGOOD rising hysteresis, channels A (blue), B (red) and C (green), as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 2% to 5%.

Variables Data Plots (Continued)

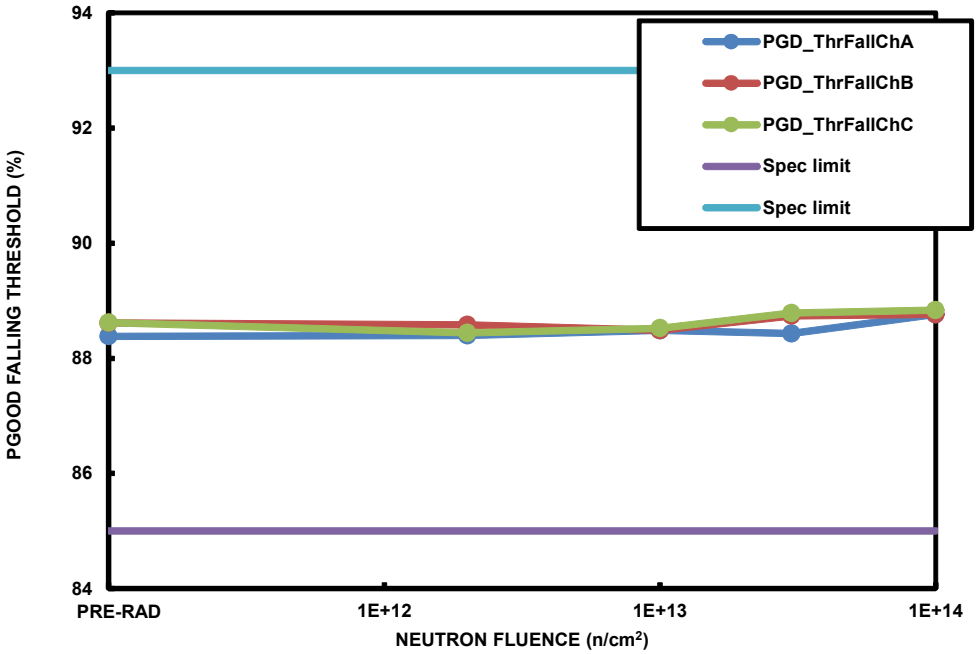

FIGURE 22. ISL70003SEH PGOOD falling threshold, channels A (blue), B (red) and C (green), as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 85% to 93%.

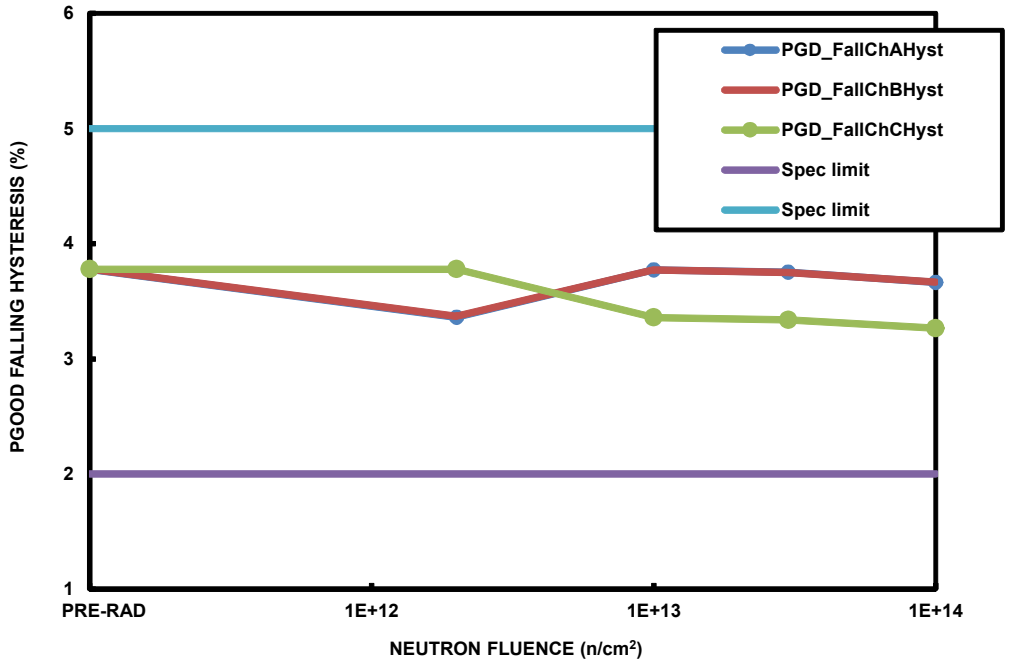

FIGURE 23. ISL70003SEH PGOOD falling hysteresis, channels A (blue), B (red) and C (green), as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 2% to 5%.

Variables Data Plots (Continued)

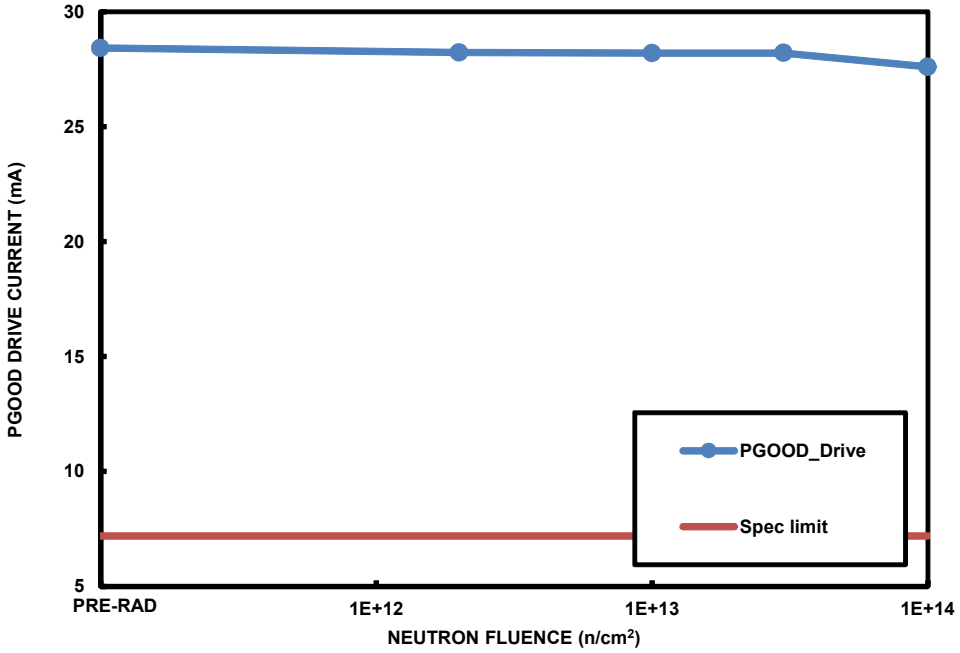

FIGURE 24. ISL70003SEH Power-Good (PGOOD) output drive current, 3V in (blue), as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limit is 7.2mA minimum.

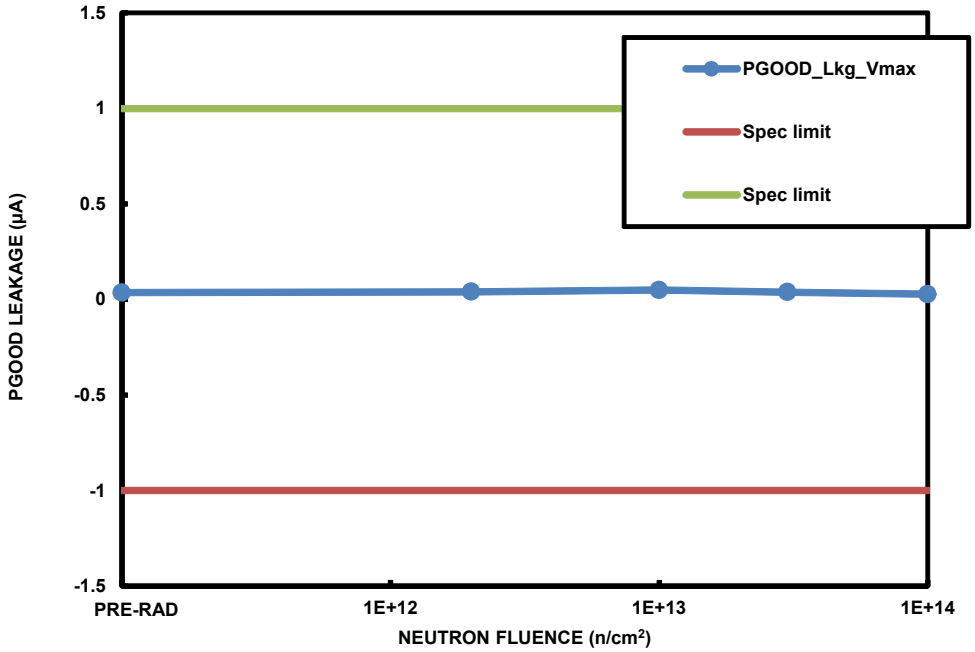

FIGURE 25. ISL70003SEH PGOOD output leakage, 3V in (blue), as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are -1.0µA to +1.0µA.

Variables Data Plots (Continued)

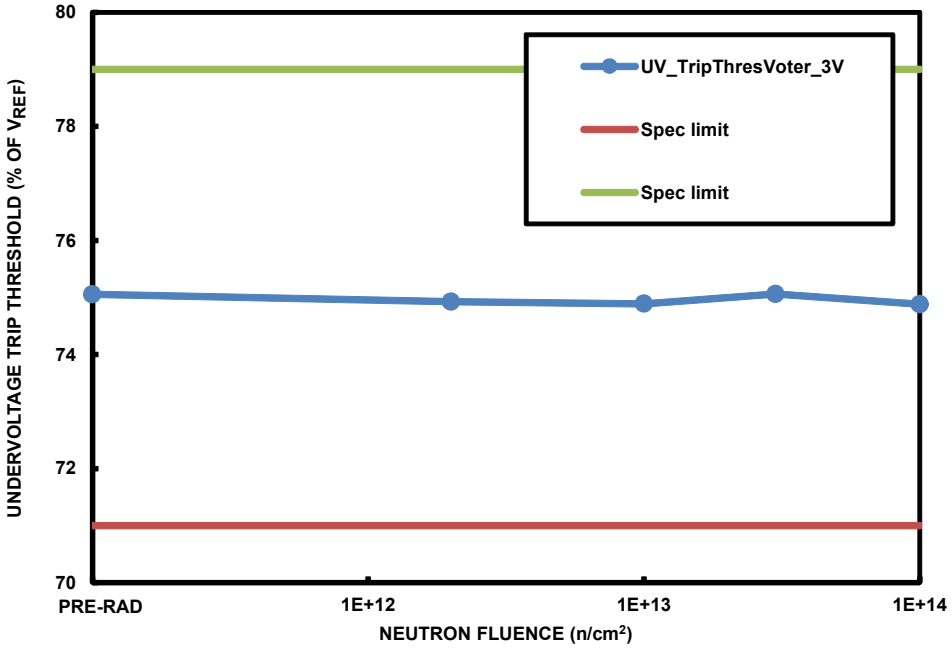

FIGURE 26. ISL70003SEH undervoltage trip threshold (blue) as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 71% to 79%.

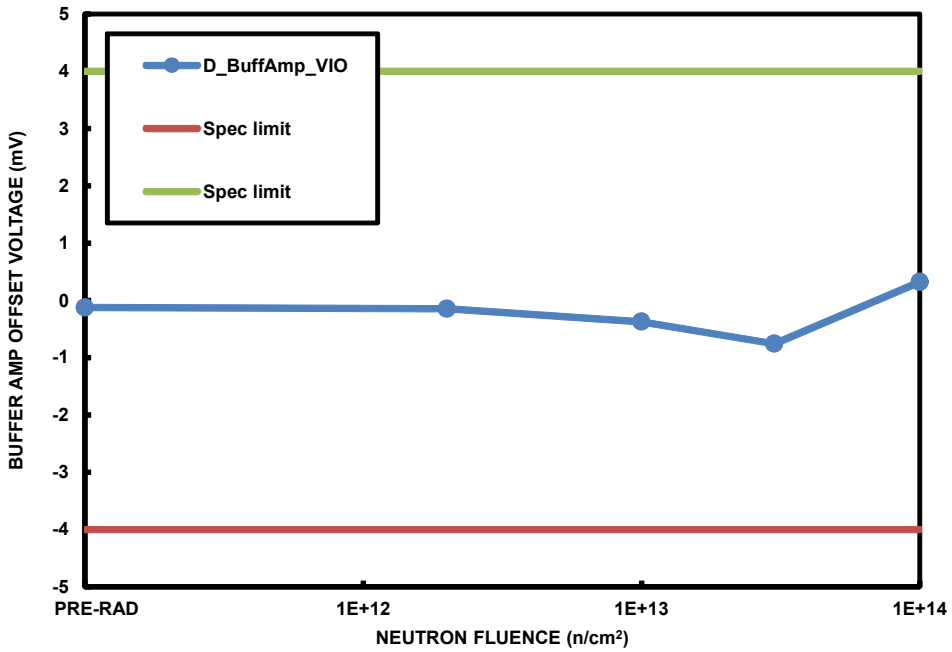

FIGURE 27. ISL70003SEH buffer amplifier input offset voltage (blue) as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The data sheet limits are -4mV to 4mV.

Variables Data Plots (Continued)

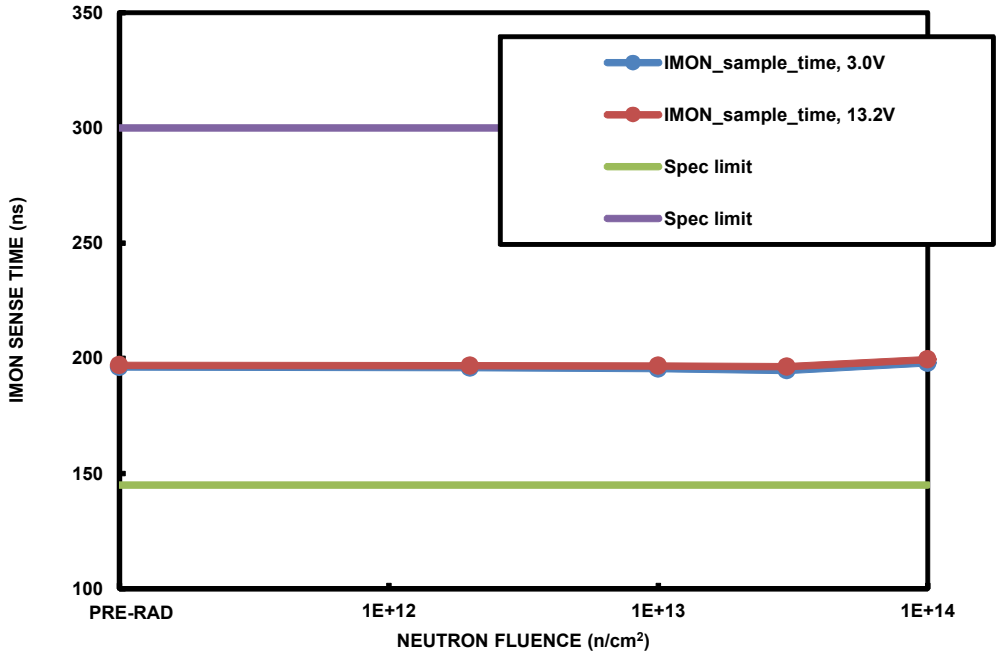

FIGURE 28. ISL70003SEH current monitor (IMON) sense time for the 3V (blue) and 13.2V (red) cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 145ns to 300ns.

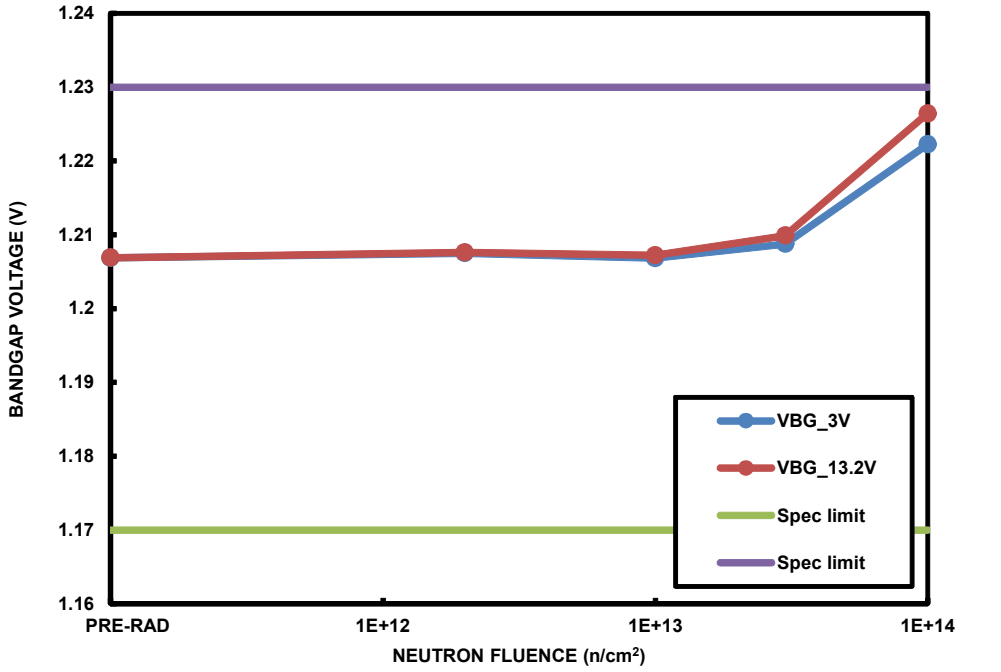

FIGURE 29. ISL70003SEH bandgap voltage for the 3V (blue) and 13.2V (red) cases, as a function of neutron irradiation, showing the median of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were 2 x 10^{12} n/cm^2 (5 samples), 1 x 10^{13} n/cm^2 (5 samples), 3 x 10^{13} n/cm^2 (5 samples) and 1 x 10^{14} n/cm^2 (5 samples). The SMD limits are 1.17V to 1.23V.

Discussion and Conclusion

This document reports the results of 1MeV equivalent neutron testing of the ISL70003SEH hardened Point-of-Load (POL) regulator. Parts were tested at 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2, 3 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2. The data is reported in Figures 2 through 29, show plots of key parameters before and after irradiation to each level. The plots show the median of each parameter as a function of neutron irradiation. The figures also show the applicable electrical limits taken from the SMD; it should be carefully noted that these limits are provided for guidance only as the ISL70003SEH is not specified for the neutron environment. All samples passed the SMD limits after 2 x 10^{12} and 1 x 10^{13} n/cm^2 but failed after 3 x 10^{13} and 1 x 10^{14} n/cm^2.

TABLE 2. REPORTED PARAMETERS

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNITS	NOTES
2	Operating Current, 500kHz	-	60/25	mA	3V and 13.2V_{IN}
3	Operating Current, 300kHz	-	60/25	mA	3V and 13.2V_{IN}
4	Standby Current, 500kHz	-	15/30	mA	3V and 13.2V_{IN}
5	Standby Current, 300kHz	-	15/30	mA	3V and 13.2V_{IN}
6	Shutdown Current, 500kHz	-	1/3	mA	3V and 13.2V_{IN}
7	Series Regulator Output Voltage	4.5	5.5	V	13.2V_{IN}
8	Series Regulator Current Limit	-50	-190	mA	13.2V_{IN}
9	POR Input Pin Voltage	0.56	0.64	V	3V and 13.2V_{IN}
10	POR Sink Current	9.6	14.4	mA	3V and 13.2V_{IN}
11	Enable low Input Current	-	10.0	µA	13.2V_{IN}
12	Enable high Input Current	-	10.0	µA	13.2V_{IN}
13	Minimum On-Time	-	320	ns	3V and 13.2V_{IN}
14	Minimum Off-Time	-	270	ns	3V and 13.2V_{IN}
15	Error Amplifier Offset Voltage	-3	3	mV	3V and 13.2V_{IN}
16	Upper Device ON-Resistance	170	700	mΩ	3V and 13.2V_{IN}
17	Lower Device ON-Resistance	90	455	mΩ	3V and 13.2V_{IN}
18	LXx low Leakage Current	-3	3	µA	3V_{IN}
19	LXx high Leakage Current	-3	3	µA	3V_{IN}
20	PGOOD Rising Threshold	107	118	%	3V_{IN}
21	PGOOD Rising Hysteresis	2	5	%	3V_{IN}
22	PGOOD Falling Threshold	85	93	%	3V_{IN}
23	PGOOD Falling Hysteresis	2	5	%	3V_{IN}
24	PGOOD Output Drive Current	7.2	-	mA	3V_{IN}
25	PGOOD Output Leakage	-1	1	µA	3V_{IN}
26	Undervoltage Trip Threshold	71	79	%	3V_{IN}
27	Buffer Amplifier Offset Voltage	-4	4	mV	3V_{IN}
28	Current Monitor Sense Time	145	300	ns	3V and 13.2V_{IN}
29	Bandgap Output Voltage	1.17	1.23	V	3V and 13.2V_{IN}

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(Rev.4.0-1 November 2017)

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