ISL78845ASEH

Neutron Testing

TR006
Rev 0.00
May 12, 2015

Introduction

This report summarizes results of 1MeV equivalent neutron testing of the ISL78845ASEH current mode PWM controller. The test was conducted in order to determine the sensitivity of the part to the Displacement Damage (DD) caused by the neutron environment. Neutron fluences ranged from $2 \times 10^{11} n/cm^2$ to $1 \times 10^{14} n/cm^2$. This project was carried out in collaboration with Honeywell Aerospace (Clearwater, FL), and their support is gratefully acknowledged.

Part Description

The ISL78845ASEH is a high performance, radiation hardened drop-in replacement for the popular 28C4x and 18C4x PWM controllers and is suitable for a wide range of power conversion applications including boost, flyback and isolated output configurations. Its fast signal propagation and output switching characteristics make this an ideal product for existing and new designs. Features include up to 13.2V operation, low operating current, 90µA typical start-up current, adjustable operating frequency to 1MHz, and high peak current drive capability with 50ns rise and fall times.

There are four variants of this part: the ISL78840SEH with rising Undervoltage Lockout (UVLO) threshold of 7V and 100% maximum duty cycle, the ISL78841SEH with rising UVLO threshold of 7V and 50% maximum duty cycle, the ISL78843SEH with rising UVLO threshold of 8.4V and 100% maximum duty cycle and finally the ISL78845ASEH with rising UVLO threshold of 8.4V and 50% maximum duty cycle. The four variants are closely similar and the ISL78845ASEH data discussed in this report is considered applicable to the other three variants.

The ISL78845ASEH is available in an 8 Ld hermetic ceramic flatpack and in die form and offers guaranteed performance across the full -55°C to +125°C military temperature range.

Test Description

Irradiation Facilities

Neutron irradiation was performed by the Honeywell team at the Fast Burst Reactor facility at White Sands Missile Range (White Sands, NM), which provides a controlled 1MeV equivalent neutron flux. Parts were tested in an unbiased configuration with all leads shorted together. As neutron irradiation activates many of the elements found in a packaged integrated circuit, the parts exposed at the higher neutron levels required (as expected) significant ‘cooldown’ time before being shipped back to Intersil (Palm Bay, FL) for electrical testing.

Characterization equipment and procedures

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 Test Method 1017. The experimental matrix consisted of six samples irradiated at $2.2 \times 10^{11} n/cm^2$, six samples irradiated at $4.4 \times 10^{11} n/cm^2$, six samples irradiated at $6.6 \times 10^{11} n/cm^2$, three samples irradiated at $1 \times 10^{12} n/cm^2$, three samples irradiated at $1 \times 10^{13} n/cm^2$ and five samples irradiated at $1 \times 10^{14} n/cm^2$. Two control units were used to insure repeatability. Samples were taken from current production inventory.

Results

Test results

Neutron testing of the ISL78845ASEH is complete and the results are reported in the balance of this report. It should be realized when reviewing the data that each neutron irradiation was made on a different 6- or 3-unit sample; this is not total dose testing, where the damage is cumulative.

Variables data

The plots in Figures 1 through 20 show data plots for key parameters before and after irradiation to each level. The plots show the median, minimum and maximum of each parameter for each of the four amplifier channels as a function of neutron irradiation. We chose to plot the median because of the small sample sizes involved. We also show the applicable electrical limits taken from the SMD, this for guidance only as the ISL78845ASEH is not specified for neutron irradiation.

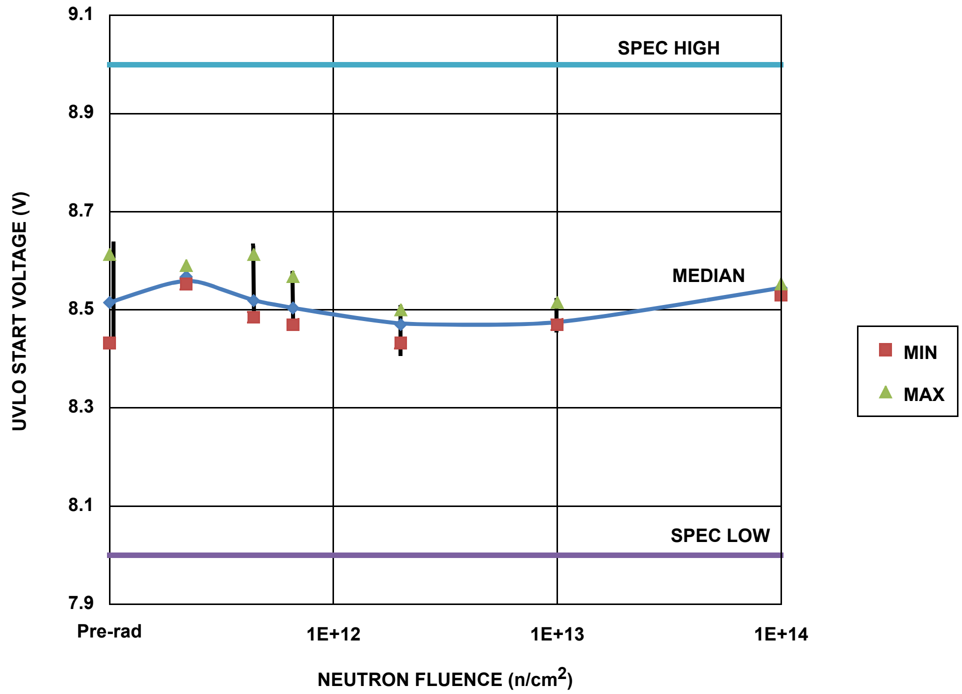

FIGURE 1. ISL78845ASEH Undervoltage Lockout (UVLO) START threshold voltage as a function of neutron irradiation, showing the median, minimum and maximum of the populations following irradiation to each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4x10^{11}n/cm^2$ (6 samples), $6.6x10^{11}$ n/cm^2 (6 samples), $1x10^{12}n/cm^2$ (3 samples), $1x10^{13}n/cm^2$ (3 samples) and $1x10^{14}n/cm^2$ (3 samples). For reference, the SMD limits are 8V to 9V. (21)

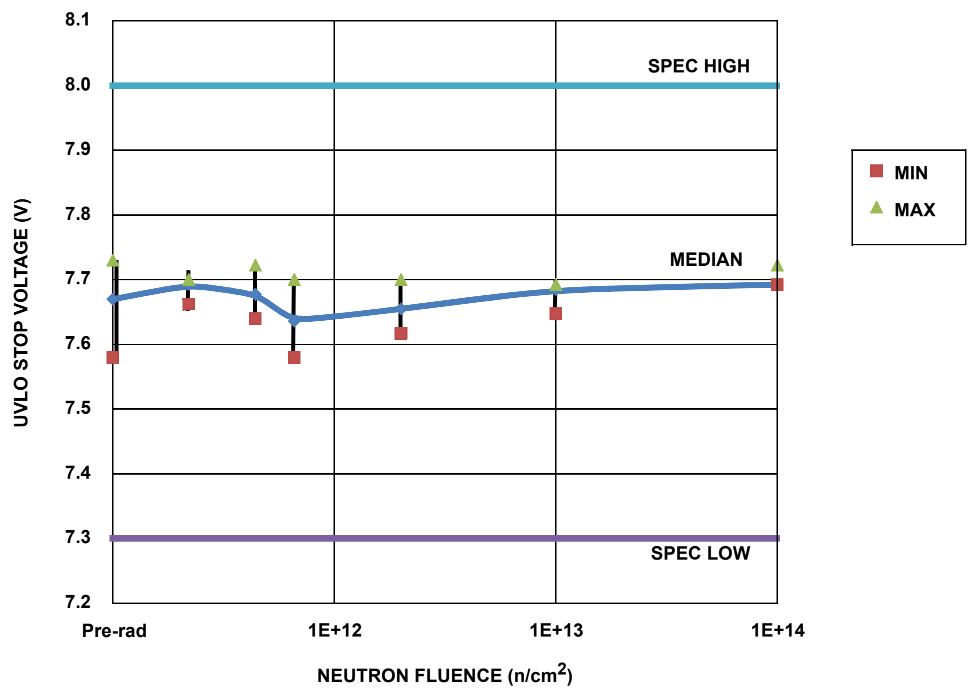

FIGURE 2. ISL78845ASEH UVLO STOP threshold voltage as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4x10^{11}n/cm^2$ (6 samples), $6.6x10^{11}$ n/cm^2 (6 samples), $1x10^{12}n/cm^2$ (3 samples), $1x10^{13}n/cm^2$ (3 samples) and $1x10^{14}n/cm^2$ (3 samples). For reference, the SMD limits are 7.3V to 8V. (22)

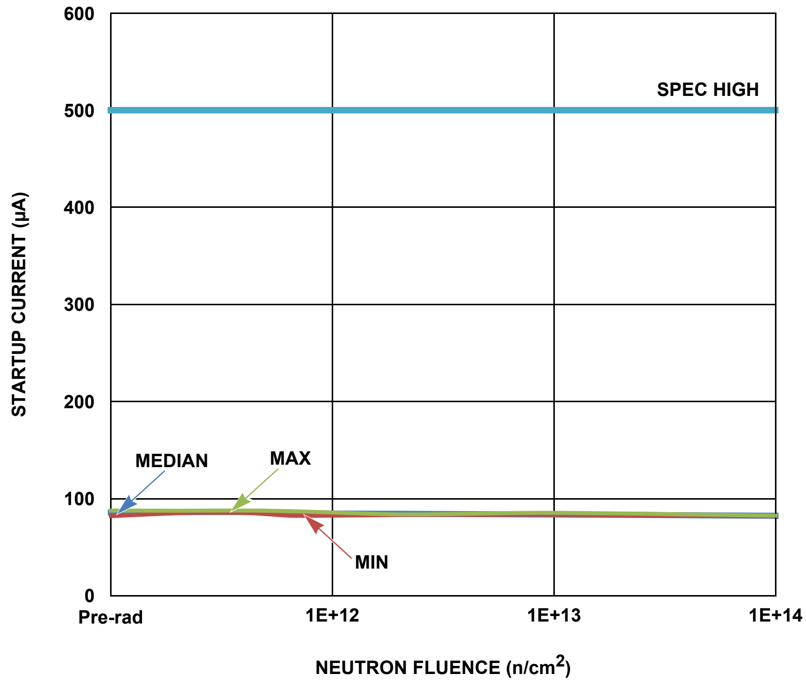

FIGURE 3. ISL78845ASEH startup current as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were 2.2 x 10^{11} n/cm^2 (6 samples), 4.4 x 10^{11} n/cm^2 (6 samples), 6.6x10^{11}n/cm^2 (6 samples), 1x10^{12}n/cm^2 (3 samples), 1x10^{13}n/cm^2 (3 samples) and 1x10^{14}n/cm^2 (3 samples). For reference, the post-irradiation SMD limit is 500µA.

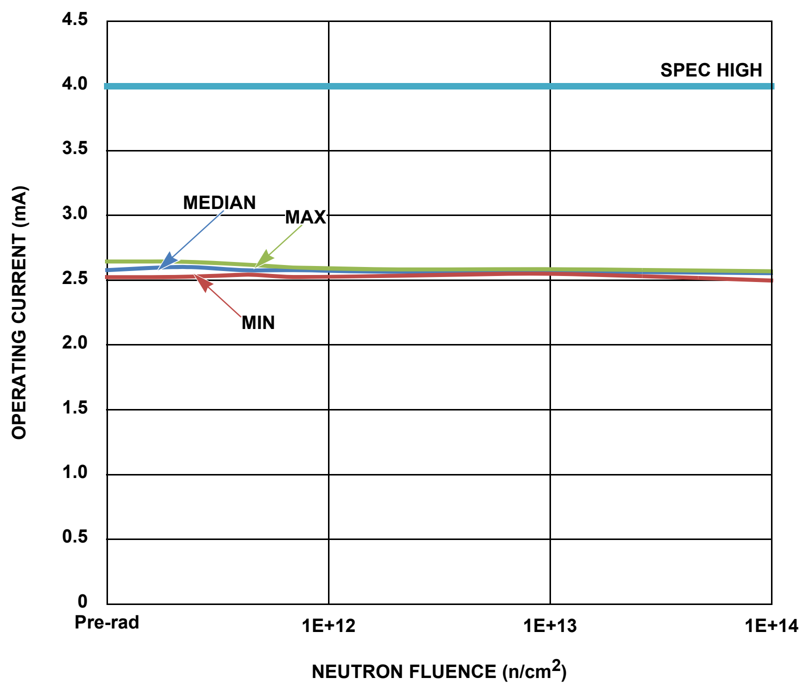

FIGURE 4. ISL78845ASEH operating current as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were 2.2x10^{11} n/cm^2 (6 samples), 4.4x10^{11} n/cm^2 (6 samples), 6.6x10^{11}n/cm^2 (6 samples), 1 x 10^{12}n/cm2 (3 samples), 1x10^{13}n/cm^2 (3 samples) and 1x10^{14} n/cm^2 (3 samples). The SMD limit is 4mA maximum.

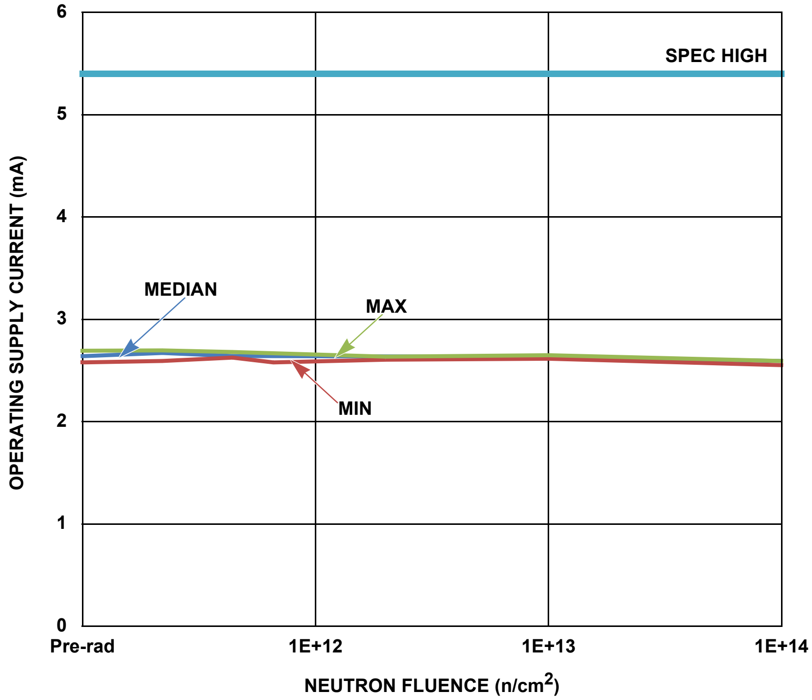

FIGURE 5. ISL78845ASEH operating supply current as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4 \times 10^{11}\ n/cm^2$ (6 samples), $6.6x10^{11}n/cm^2$ (6 samples), $1x10^{12}n/cm^2$ (3 samples), $1x10^{13}n/cm^2$ (3 samples) and $1 \times 10^{14}\ n/cm^2$ (3 samples). The SMD limit is 5.5mA maximum.

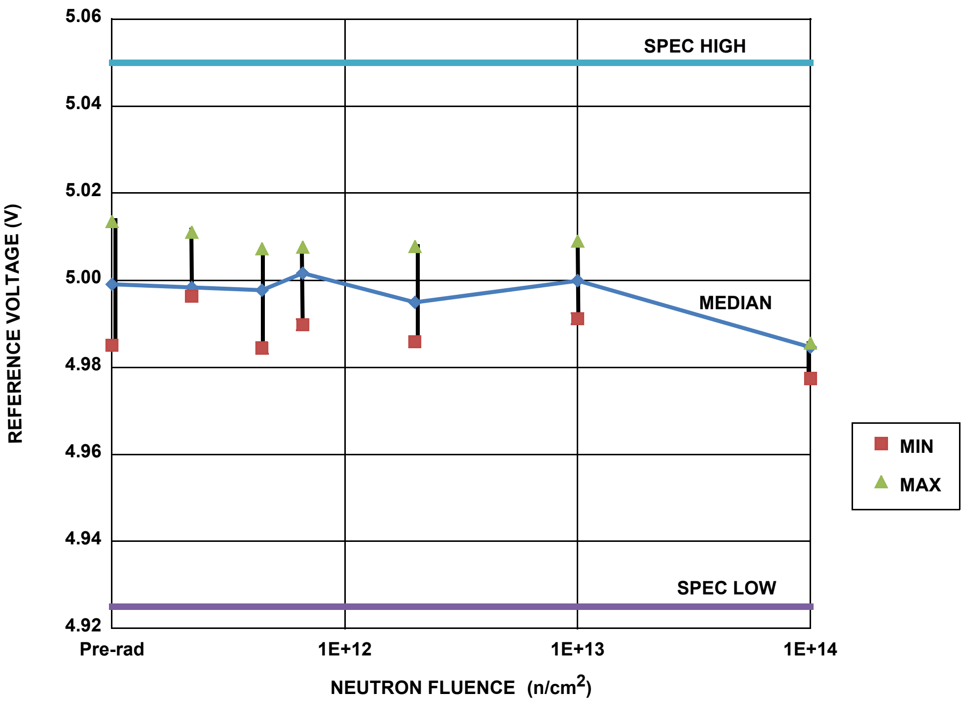

FIGURE 6. ISL78845ASEH reference voltage accuracy as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4x10^{11}n/cm^2$ (6 samples), $6.6x10^{11}n/cm^2$ (6 samples), $1x10^{12}n/cm^2$ (3 samples), $1x10^{13}n/cm^2$ (3 samples) and $1x10^{14}n/cm^2$ (3 samples). The SMD limits are 4.925V to 5.050V.

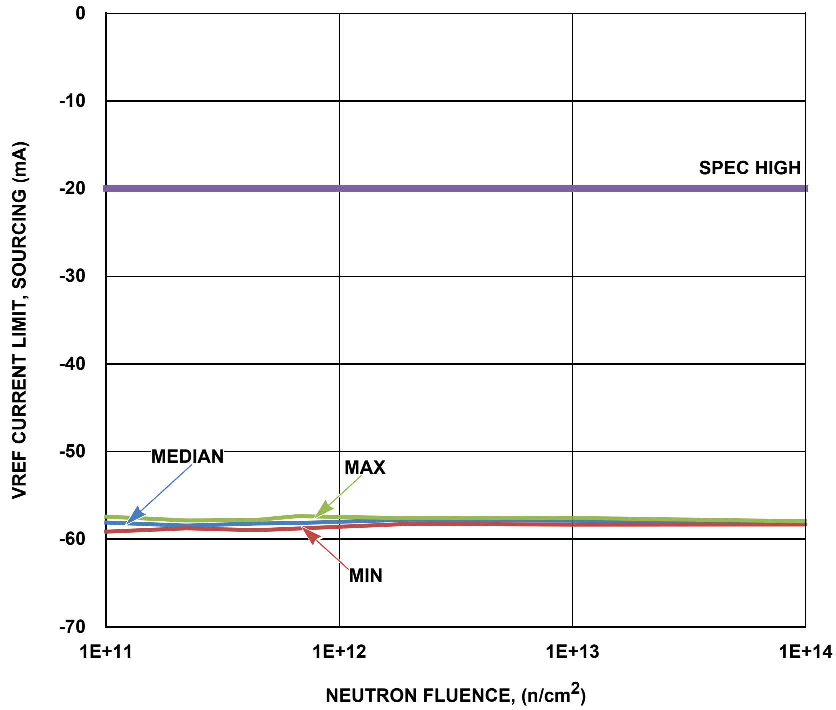

FIGURE 7. ISL78845ASEH reference current limit, sourcing, as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were 2.2×10^{11}n/cm^2 (6 samples), 4.4×10^{11}n/cm^2 (6 samples), 6.6×10^{11}n/cm^2 (6 samples), 1×10^{12}n/cm^2 (3 samples), 1×10^{13}n/cm^2 (3 samples) and 1×10^{14}n/cm^2 (3 samples). The SMD limit is -20mA minimum.

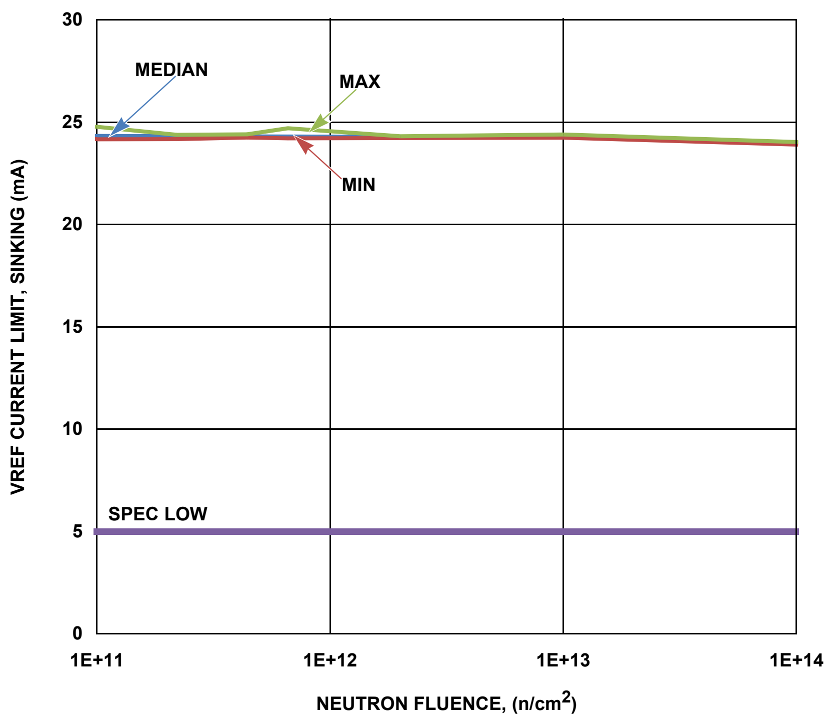

FIGURE 8. ISL78845ASEH reference current limit, sinking, as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were 2.2×10^{11}n/cm^2 (6 samples), 4.4×10^{11}n/cm^2 (6 samples), 6.6×10^{11}n/cm^2 (6 samples), 1×10^{12}n/cm^2 (3 samples), 1×10^{13}n/cm^2 (3 samples) and 1×10^{14}n/cm^2 (3 samples). The SMD limit is 5mA minimum.

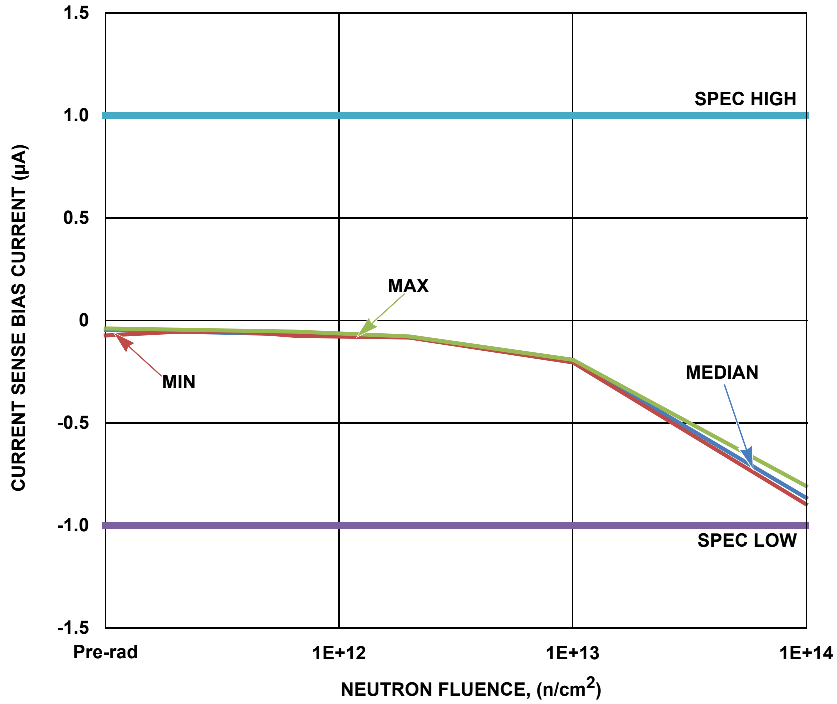

FIGURE 9. ISL78845ASEH current sense input bias current as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4x10^{11}n/cm^2$ (6 samples), $6.6x10^{11}$ n/cm^2 (6 samples), $1x10^{12}n/cm^2$ (3 samples), $1x10^{13}n/cm^2$ (3 samples) and $1x10^{14}n/cm^2$ (3 samples). The SMD limits are -1µA to 1µA.

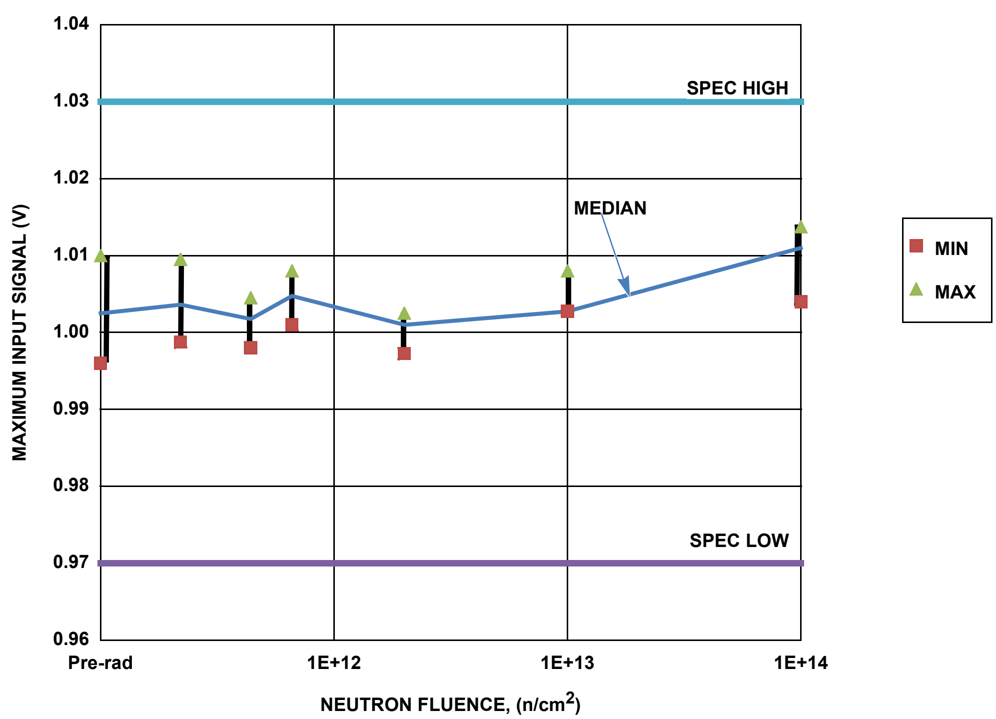

FIGURE 10. ISL78845ASEH current sense maximum input signal as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4x10^{11}n/cm^2$ (6 samples), $6.6x10^{11}n/cm^2$ (6 samples), $1x10^{12}n/cm^2$ (3 samples), $1x10^{13}n/cm^2$ (3 samples) and 1×10^{14} n/cm^2 (3 samples). The SMD limits are 0.97V to 1.03V.

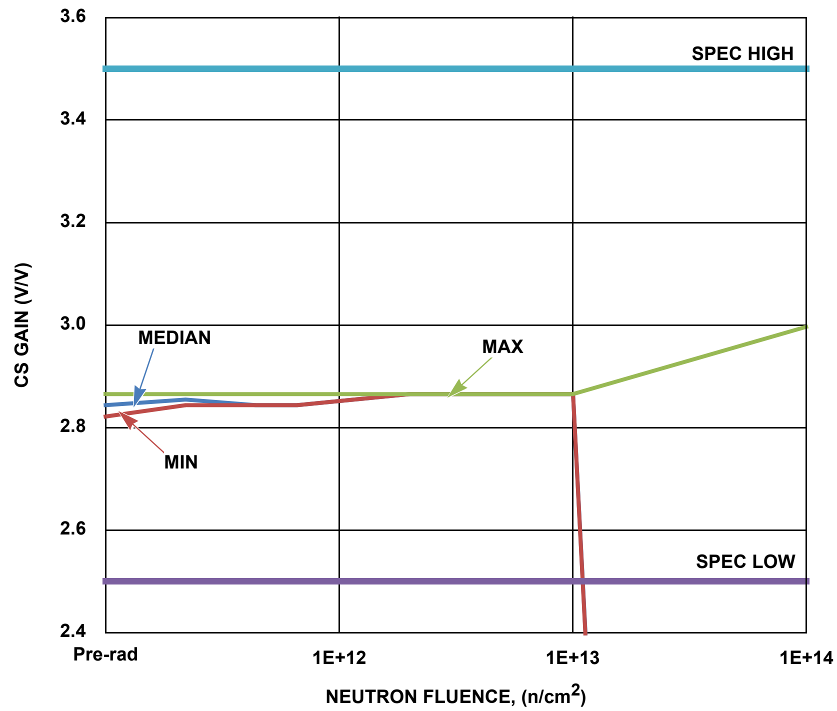

FIGURE 11. ISL78845ASEH current sense gain ($A_{CS} = \Delta V_{COMP} / \Delta V_{CS}$) as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4x10^{11}n/cm^2$ (6 samples), $6.6x10^{11}n/cm^2$ (6 samples), $1x10^{12}$ n/cm^2 (3 samples), $1x10^{13}n/cm^2$ (3 samples) and $1x10^{14}n/cm^2$ (3 samples). The SMD limits are 2.5V/V to 3.5V/V. Two out of three samples were nonfunctional after irradiation to $1x10^{14}n/cm^2$.

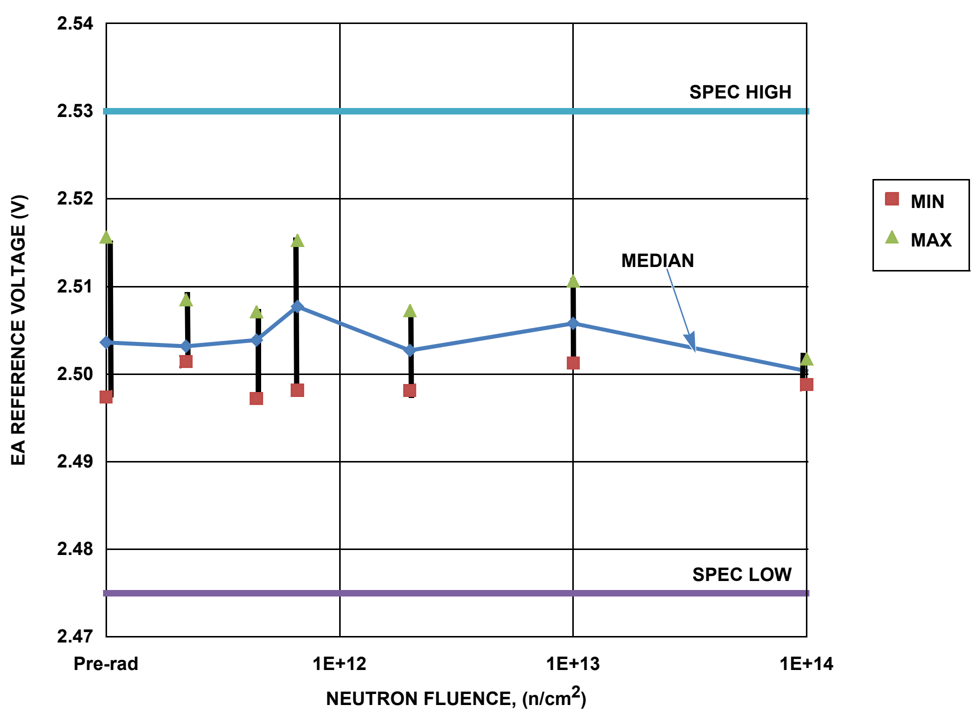

FIGURE 12. ISL78845ASEH error amplifier reference as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4x10^{11}n/cm^2$ (6 samples), $6.6x10^{11}n/cm^2$ (6 samples), $1x10^{12}$ n/cm^2 (3 samples), $1x10^{13}n/cm^2$ (3 samples) and $1x10^{14}n/cm^2$ (3 samples). The SMD limits are 2.475V to 2.530V.

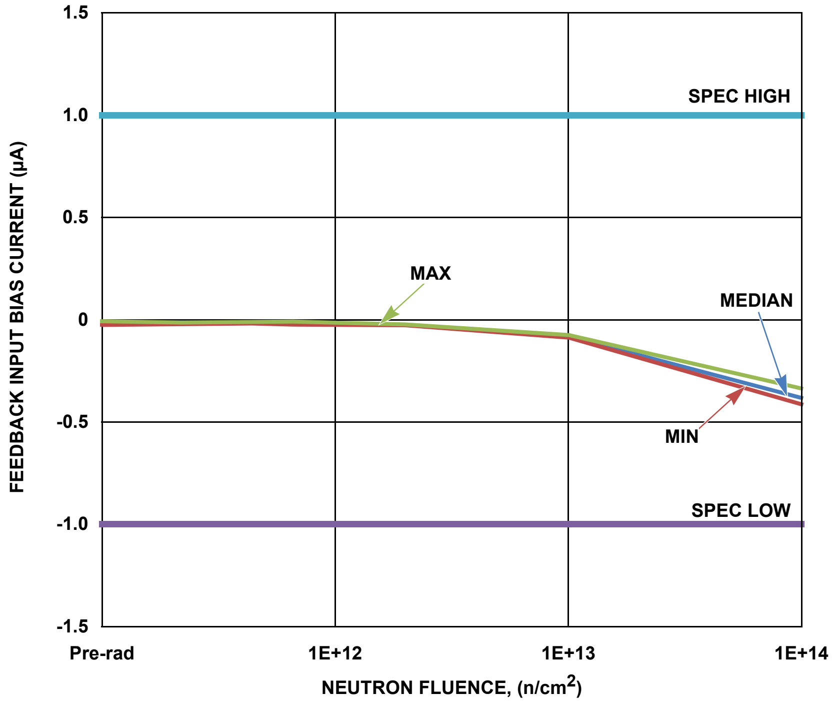

FIGURE 13. ISL78845ASEH error amplifier input bias current as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were 2.2×10^{11}n/cm^2 (6 samples), 4.4×10^{11}n/cm^2 (6 samples), 6.6×10^{11}n/cm^2 (6 samples), 1×10^{12}n/cm^2 (3 samples), 1×10^{13}n/cm^2 (3 samples) and 1×10^{14}n/cm^2 (3 samples). The SMD limits are -1µA to 1µA.

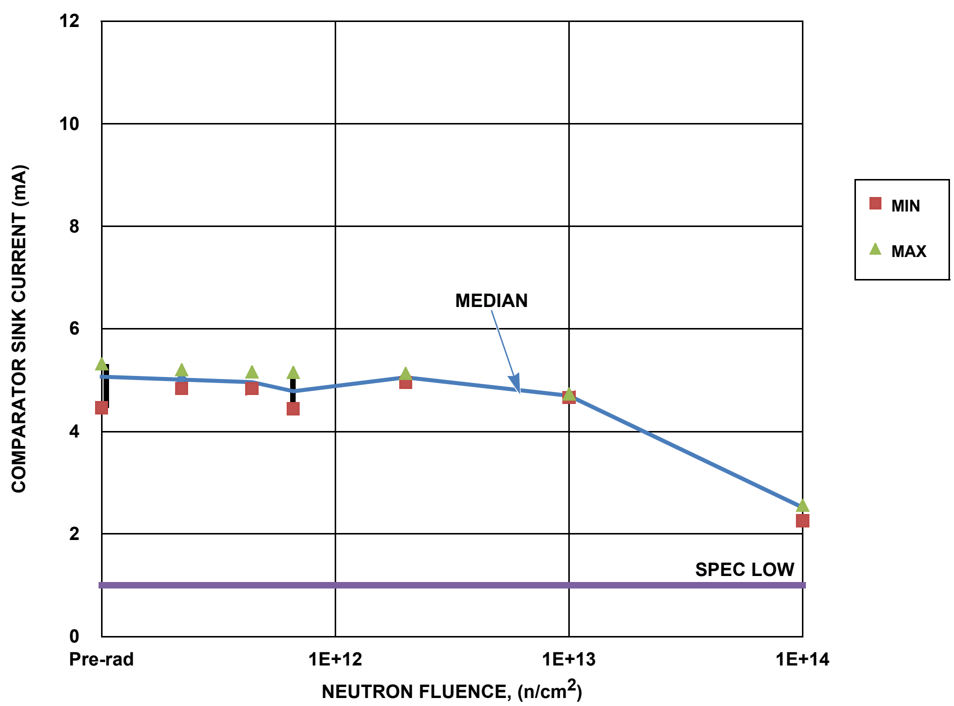

FIGURE 14. ISL78845ASEH error amplifier sink current as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were 2.2×10^{11}n/cm^2 (6 samples), 4.4×10^{11}n/cm^2 (6 samples), 6.6×10^{11}n/cm^2 (6 samples), 1×10^{12}n/cm^2 (3 samples), 1×10^{13}n/cm^2 (3 samples) and 1×10^{14}n/cm^2 (3 samples). The SMD limit is 1mA minimum.

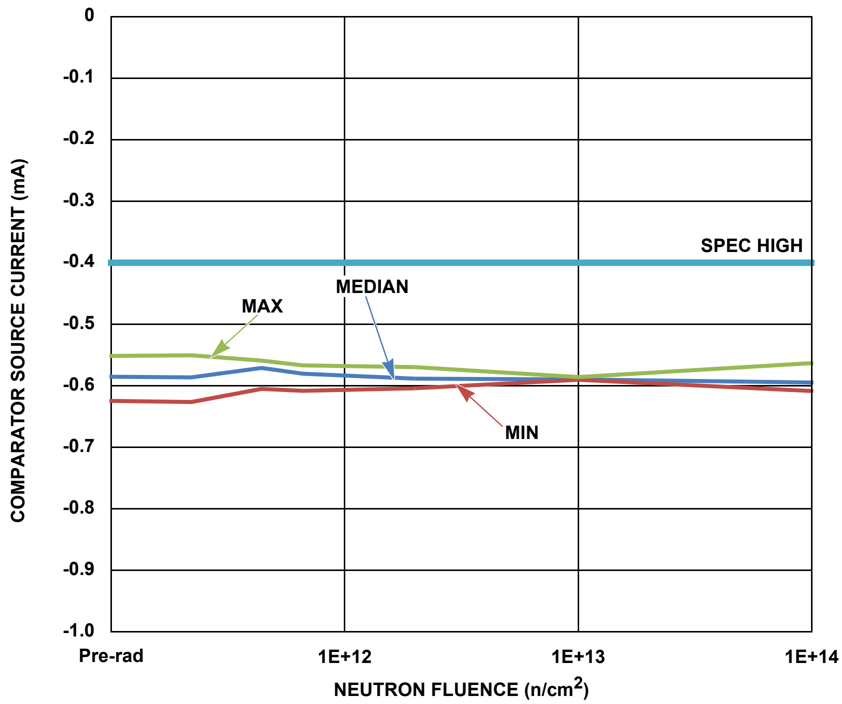

FIGURE 15. ISL78845ASEH error amplifier source current as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4x10^{11}n/cm^2$ (6 samples), $6.6x10^{11}n/cm^2$ (6 samples), $1x10^{12}n/cm^2$ (3 samples), $1x10^{13}n/cm^2$ (3 samples) and $1x10^{14}n/cm^2$ (3 samples). The SMD limit is -0.4mA minimum.

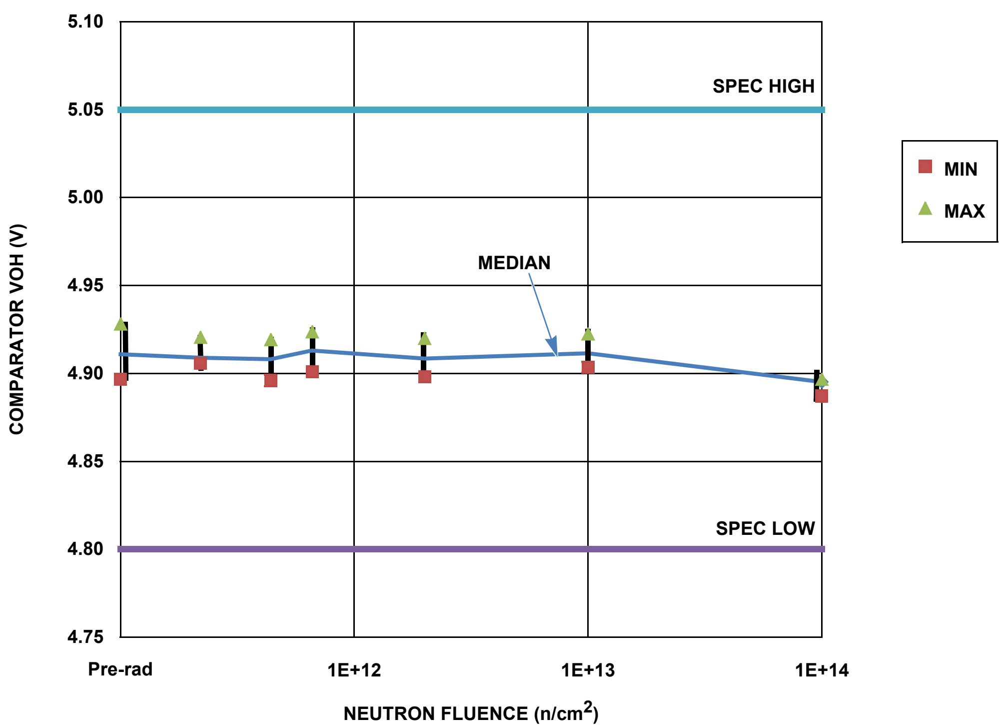

FIGURE 16. ISL78845ASEH error amplifier HIGH output voltage as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2x10^{11}n/cm^2$ (6 samples), $4.4x10^{11}n/cm^2$ (6 samples), $6.6x10^{11}n/cm^2$ (6 samples), $1x10^{12}n/cm^2$ (3 samples), $1x10^{13}n/cm^2$ (3 samples) and $1x10^{14}n/cm^2$ (3 samples). The SMD limits are 4.80V to 5.050V.

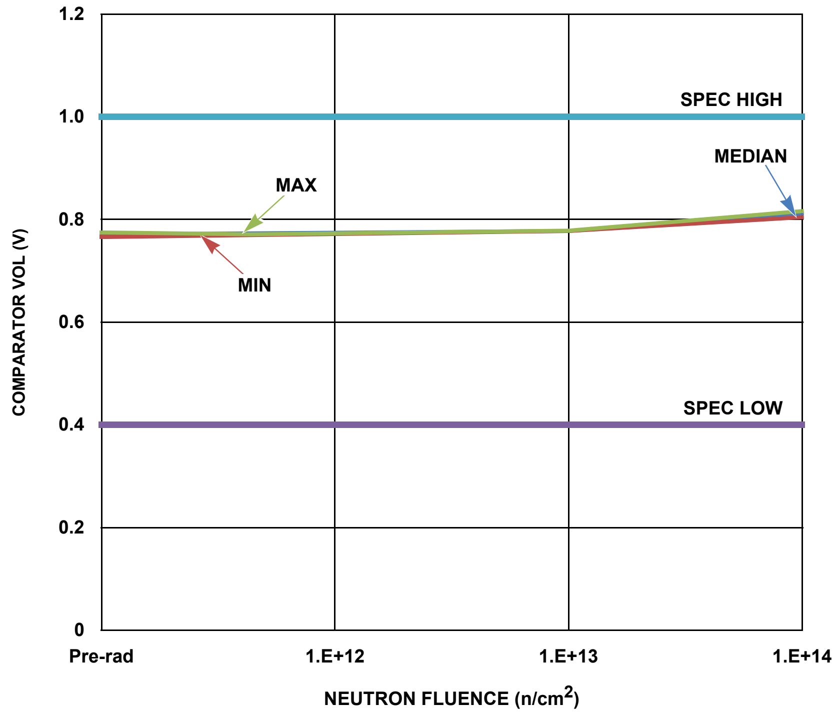

FIGURE 17. ISL78845ASEH error amplifier LOW output voltage as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2 \times 10^{11} n/cm^2$ (6 samples), $4.4 \times 10^{11} n/cm^2$ (6 samples), $6.6 \times 10^{11} n/cm^2$ (6 samples), $1 \times 10^{12} n/cm^2$ (3 samples), $1 \times 10^{13} n/cm^2$ (3 samples) and $1 \times 10^{14} n/cm^2$ (3 samples). The SMD limits are 0.4V to 1V.

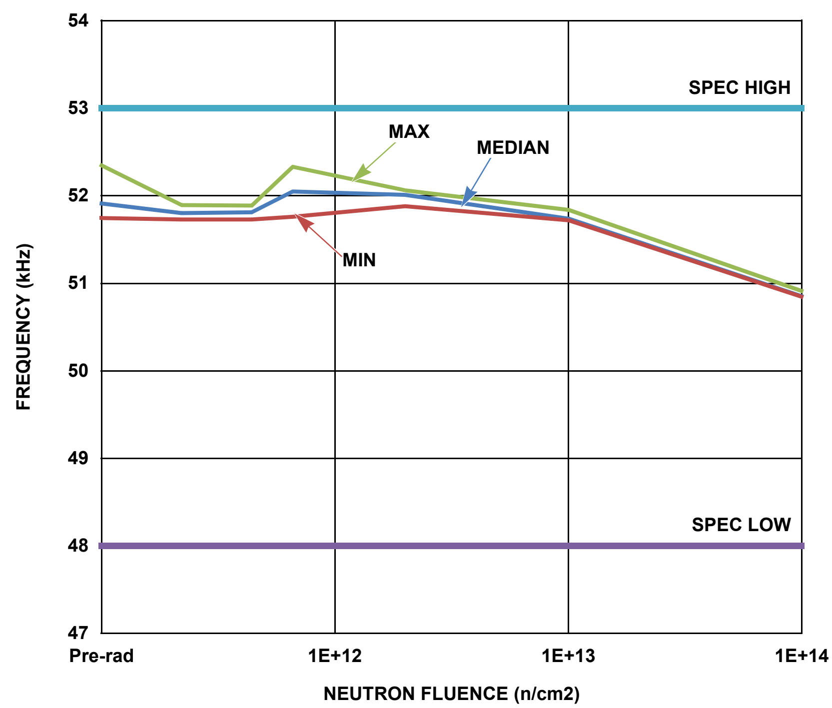

FIGURE 18. ISL78845ASEH oscillator frequency as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were $2.2 \times 10^{11} n/cm^2$ (6 samples), $4.4 \times 10^{11} n/cm^2$ (6 samples), $6.6 \times 10^{11} n/cm^2$ (6 samples), $1 \times 10^{12} n/cm^2$ (3 samples), $1 \times 10^{13} n/cm^2$ (3 samples) and $1 \times 10^{14} n/cm^2$ (3 samples). The SMD limits are 48kHz to 53kHz.

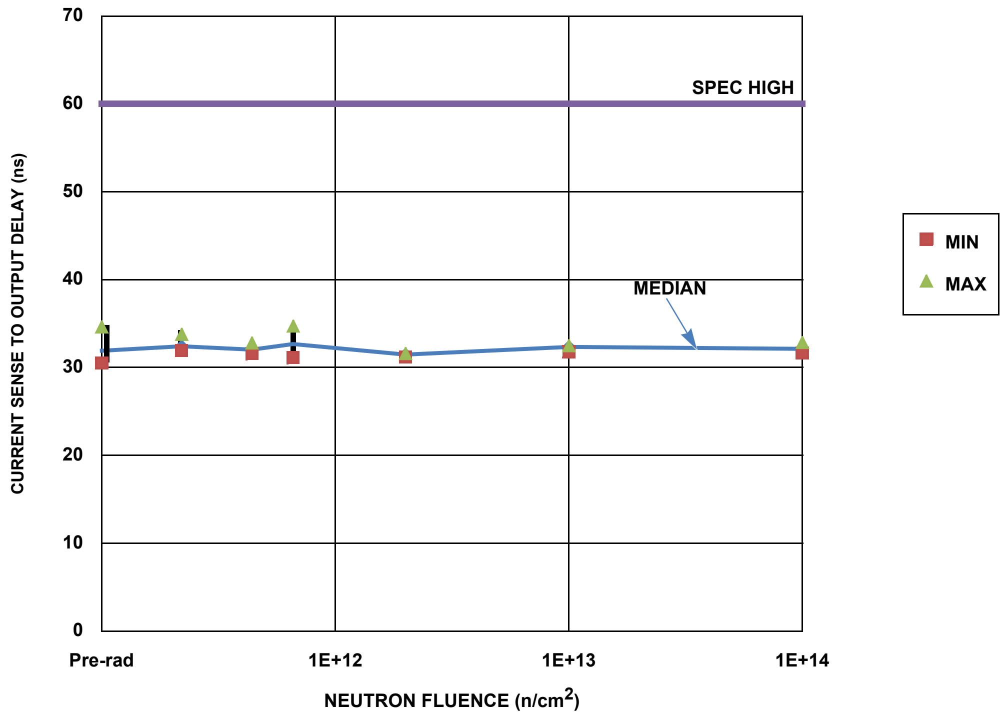

FIGURE 19. **ISL78845ASEH current sense to output delay as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were 2.2×10^{11}n/cm^2 (6 samples), 4.4×10^{11}n/cm^2 (6 samples), 6.6×10^{11}n/cm^2 (6 samples), 1×10^{12}n/cm^2 (3 samples), 1×10^{13}n/cm^2 (3 samples) and 1×10^{14}n/cm^2 (3 samples). The SMD limit is 60ns maximum.**

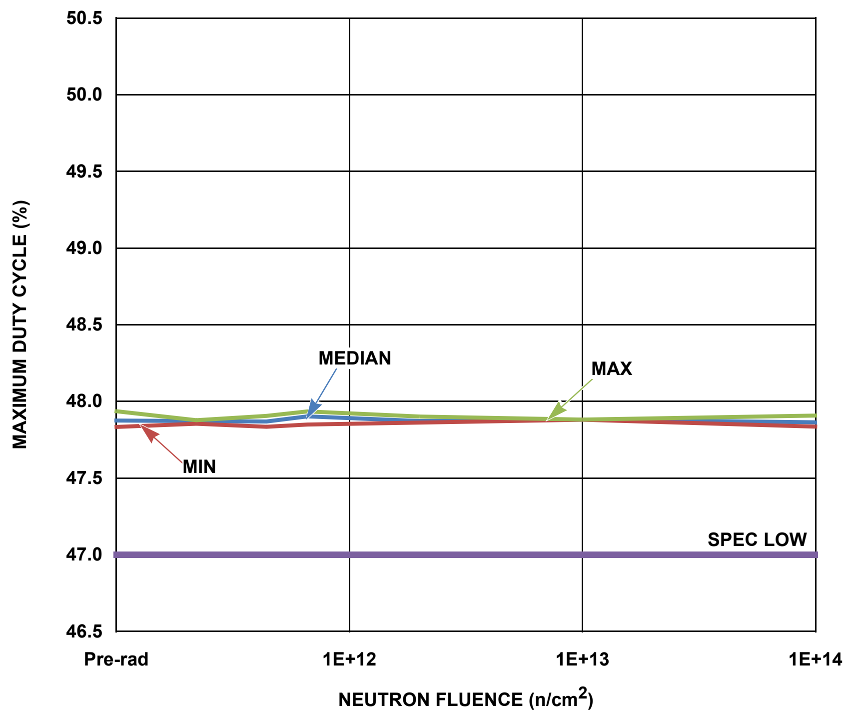

FIGURE 20. **ISL78845ASEH maximum duty cycle as a function of neutron irradiation, showing the median, minimum and maximum of the populations at each level. Neutron fluences and sample sizes (in parentheses) were 2.2×10^{11}n/cm^2 (6 samples), 4.4×10^{11}n/cm^2 (6 samples), 6.6×10^{11}n/cm^2 (6 samples), 1×10^{12}n/cm^2 (3 samples), 1×10^{13}n/cm^2 (3 samples) and 1×10^{14}n/cm^2 (3 samples). The SMD limit is 47% minimum.**

Discussion and conclusion

This document reports the results of neutron testing of the ISL78845ASEH current mode PWM controller. Samples were irradiated to levels of $2.2x10^{11}n/cm^2$, $4.4x10^{11}n/cm^2$, $6.6x10^{11}n/cm^2$, $1x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$, with sample sizes of six each for the first three cells and three each for the last three cells. It should again be carefully realized when interpreting the attributes and variables data that each neutron irradiation was performed on a different sample; this is not total dose testing, where a single set of samples is used and the damage is cumulative. ATE characterization testing was performed before and after the irradiations, and two control units were used to insure repeatable data. Variables data for monitored parameters is presented in Figures 1 through 20.

The ISL78845ASEH is not formally designed for neutron hardness. The part is built in a junction-isolated submicron BiCMOS process; the bipolar transistors are minority carrier devices, obviously, and may be expected to be sensitive to Displacement Damage (DD) at the higher neutron levels. This expectation turned out to be correct. We will discuss the results on a parameter by parameter basis and then draw some conclusions.

The Undervoltage Lockout (UVLO) START and STOP threshold voltages (Figures 1 and 2) showed good stability after all neutron levels.

The startup current, operating current and operating supply current (Figures 3 through 5) showed excellent stability after all neutron levels.

The reference voltage accuracy (Figure 6) showed good stability after all neutron levels, with a gradually decreasing range at the higher levels.

The reference sourcing and sinking current limits (Figures 7 and 8) showed excellent stability after all neutron levels.

The current sense input bias current (Figure 9) showed good stability to the $1x10^{13}n/cm^2$ level but decreased significantly after $1x10^{14}n/cm^2$. The parameter was near the lower SMD limit after $1x10^{14}n/cm^2$.

The current sense maximum input signal (Figure 10) showed some degradation at the highest two neutron levels but remained well within the SMD limits.

The current sense gain (Figure 11) showed good stability at the lower levels but was nonfunctional after $1x10^{14}n/cm^2$, with two of the three samples failing this test.

The error amplifier reference voltage (Figure 12) showed good stability after all neutron levels.

The error amplifier input bias current and sink current (Figures 13 and 14) showed good stability to the $1x10^{13}n/cm^2$ level but decreased significantly after $1x10^{14}n/cm^2$. Both parameters remained within the SMD limits.

The error amplifier source current (Figure 15) showed good stability after all neutron levels.

The error amplifier HIGH and LOW output voltages (Figures 16 and 17) showed good stability to the $1x10^{13}n/cm^2$ level with slight decreases after $1x10^{14}n/cm^2$.

The oscillator frequency (Figure 18) showed good stability to the $1x10^{13}n/cm^2$ level but decreased significantly after $1x10^{14}n/cm^2$. The parameter remained well within the SMD limits.

The current sense to output delay (Figure 19) showed good stability after all neutron levels.

The maximum duty cycle (Figure 20) showed good stability after all neutron levels.

We conclude that the ISL78845ASEH is capable of post $1x10^{13}n/cm^2$ operation (likely with some relaxation of parametric specifications for some parameters) within the SMD post-total dose parameters. The part is not capable of post $1x10^{14}n/cm^2$ operation as it was nonfunctional, failing the current sense gain parameter.

Appendices

TABLE 1. REPORTED PARAMETERS

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNIT
1	UVLO START Threshold Voltage	8	9	V
2	UVLO STOP Threshold Voltage	7.3	8	V
3	Startup Current	-	500	µA
4	Operating Current	-	4	mA
5	Operating Supply Current	-	5.5	mA
6	Reference Voltage Accuracy	4.925	5.050	V
7	Reference Current Limit, Sourcing	-20	-	mA
8	Reference Current Limit, Sinking	5	-	mA
9	Current Sense Input Bias Current	-1	1	µA
10	Current Sense Maximum Input Signal	0.97	1.03	V
11	Current Sense Gain	2.5	3.5	V/V
12	Error Amplifier Reference Voltage	2.475	2.530	V
13	Error Amplifier Input Bias Current	-1	1	µA
14	Error Amplifier Sink Current	1	-	mA
15	Error Amplifier Source Current	-0.4	-	mA
16	Error Amplifier HIGH Output Voltage	4.80	5.05	V
17	Error Amplifier LOW Output Voltage	0.4	1	V
18	Oscillator Frequency	48	53	kHz
19	Current Sense To Output Delay	-	60	ns
20	Maximum Duty Cycle	47	-	%

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