ISL70444SEH

Neutron Testing

TR008
Rev 0.00
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Introduction

This report summarizes results of 1MeV equivalent neutron testing of the ISL70444SEH quad operational amplifier (op amp). 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 5×10^{11}n/cm^2 to 1×10^{14}n/cm^2 in an approximately logarithmic sequence. This project was carried out in collaboration with Honeywell Aerospace (Clearwater, FL), and their support is gratefully acknowledged.

Part Description

The ISL70444SEH features four low-power operational amplifiers optimized to provide maximum dynamic range. These op amps feature a unique combination of rail-to-rail operation on the input and output as well as a slew rate enhanced front end, providing ultra fast slew rates that are proportional to a given step size, increasing accuracy under transient conditions. The part also offers low power, low input offset voltage and low temperature drift, making it ideal for applications requiring both high DC accuracy and AC performance. With <5µs recovery from single-event transients (SET) at an LET of 86.4MeV•cm^2/mg), the number of external filtering components needed is drastically reduced. The ISL70444SEH is also immune to single-event latch-up (SEL) as it is fabricated in Intersil's proprietary PR40 Silicon On Insulator (SOI) process. The part is designed to operate over a single supply range of 2.7V to 40V or a split supply voltage range of ±1.35V to ±20V. Applications for these amplifiers include precision payload instrumentation, data acquisition and precision power supply controls. The ISL70444SEH is available in a 14 Ld hermetic ceramic flatpack or in die form. It offers guaranteed performance over the full -55°C to +125°C military temperature range. Key pre- and post-radiation specifications follow, with parametric limits shown for ±18V supplies.

- Input offset voltage. . . . . ±400µV post-irradiation
- Input offset voltage TC . . . . .0.5µV/°C typical
- Input bias current (V_{CM} = 0V) . . . . . . 370nA post-irradiation
- Supply current, per channel. . . . . .2.4mA post-irradiation
- Gain-bandwidth product. . . . . 19MHz typical
- Slew rate . . . . 60V/µs post-irradiation
- Operating temperature range . . . . -55°C to +125°C

Test Description

Irradiation Facility

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 open. 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

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 five samples irradiated at 5×10^{11} n/cm^2, five samples irradiated at 2×10^{12}n/cm^2, five samples irradiated at 1×10^{13}n/cm^2 and five samples irradiated at 1×10^{14}n/cm^2. Two control units were used.

Results

Test Results

Neutron testing of the ISL70444SEH 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 5-unit sample; this is not total dose testing, where the damage is cumulative.

Variables Data

The plots in Figures 1 through 12 show data plots for key parameters before and after irradiation to each level. The plots show the average, minimum and maximum of each parameter for each of the four amplifier channels as a function of neutron irradiation. We show the post - total dose irradiation electrical limits taken from the SMD for reference only, as the ISL70444SEH is not specified for neutron irradiation.

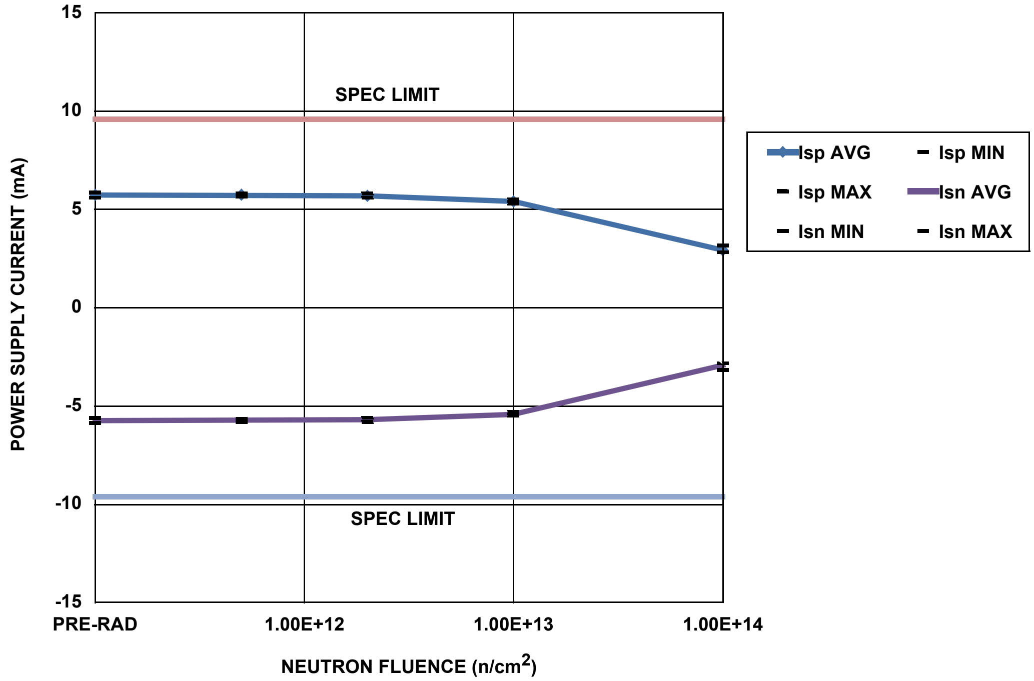

FIGURE 1. ISL70444SEH positive and negative power supply current, sum of all four channels, as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}$ n/cm^2), with two control units. The post-total dose irradiation SMD limits are -9.6mA and +9.6mA.

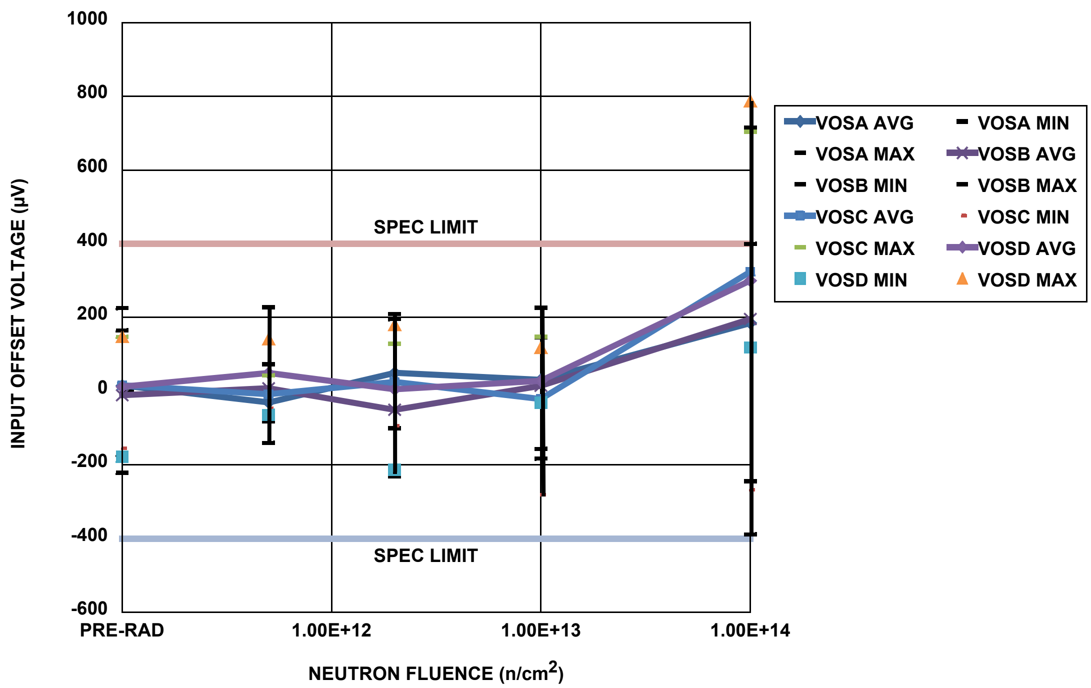

FIGURE 2. ISL70444SEH input offset voltage as a function of neutron irradiation, each channel, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limits are -400.0µV to +400.0µV.

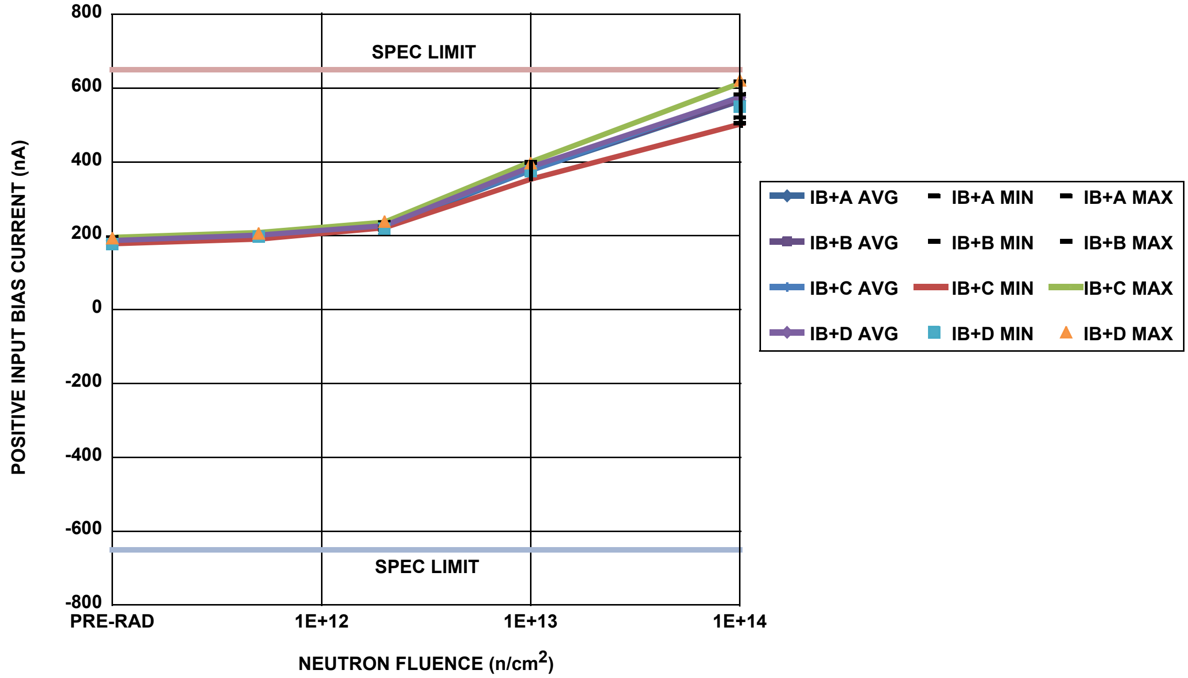

FIGURE 3. ISL70444SEH positive input bias current as a function of neutron irradiation, each channel, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limits are -650.0nA to +650.0nA.

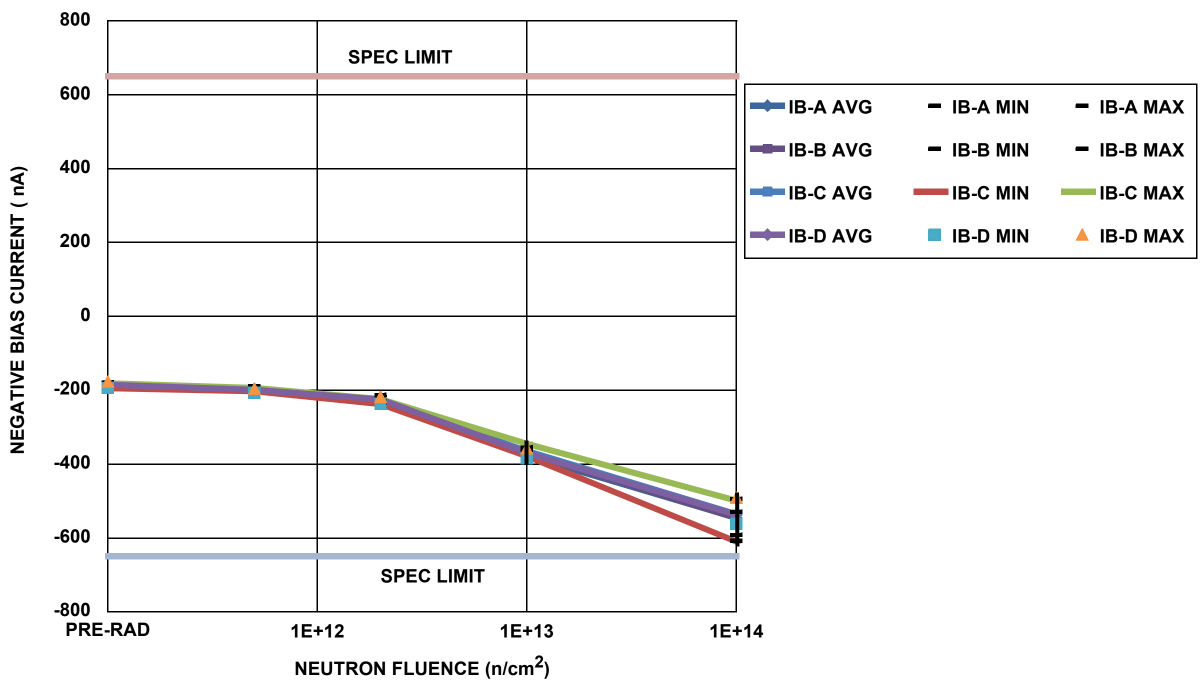

FIGURE 4. ISL70444SEH negative input bias current as a function of neutron irradiation, each channel, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limits are -650.0nA to +650.0nA.

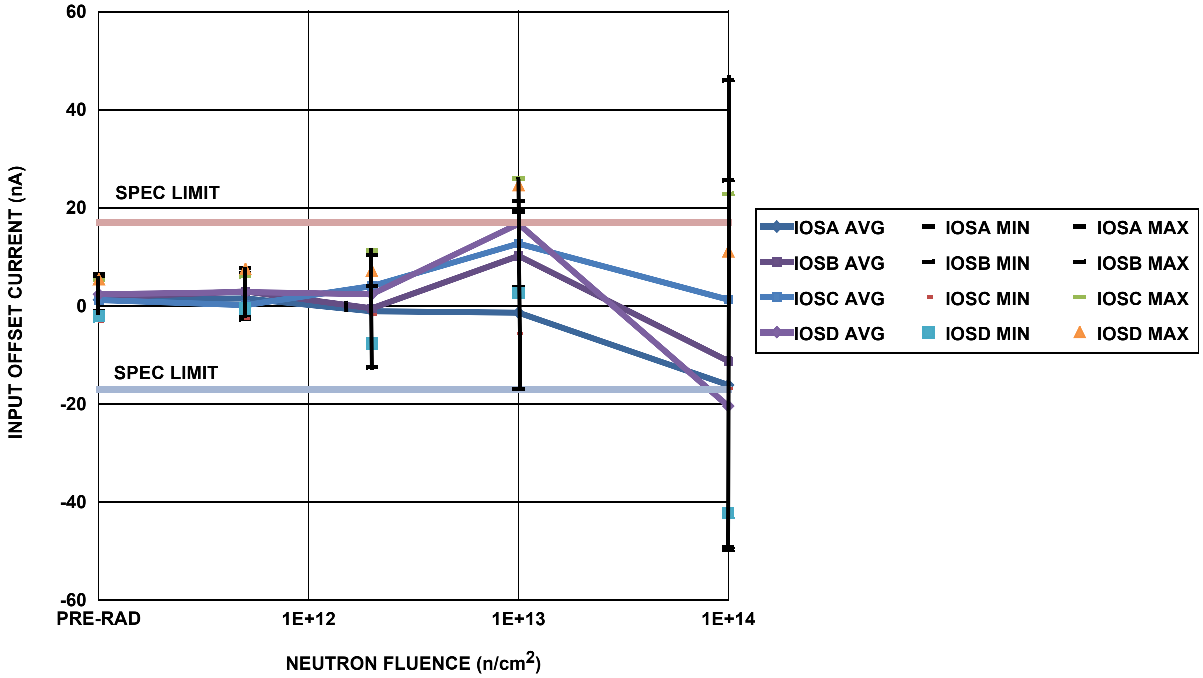

FIGURE 5. ISL70444SEH input offset current as a function of neutron irradiation, each channel, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limits are -17.0nA to +17.0nA.

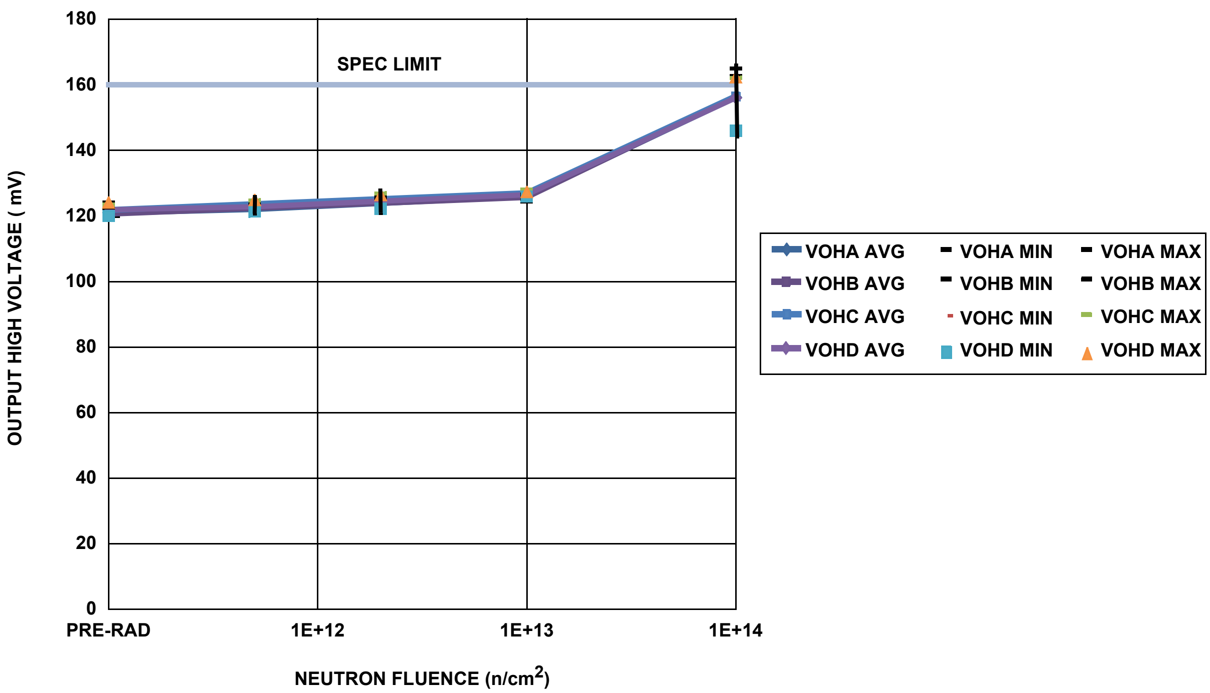

FIGURE 6. ISL70444SEH output HIGH voltage as a function of neutron irradiation, each channel, no load, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limit is 160mV maximum.

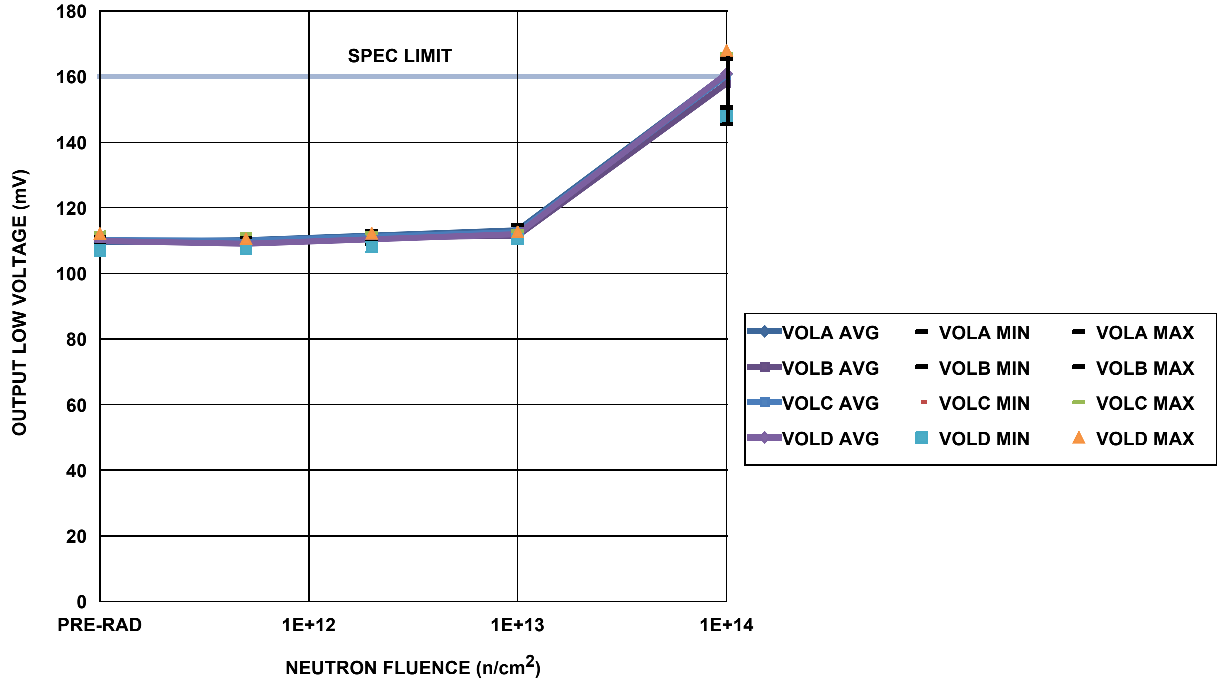

FIGURE 7. ISL70444SEH output LOW voltage as a function of neutron irradiation, no load, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limit is 160mV maximum.

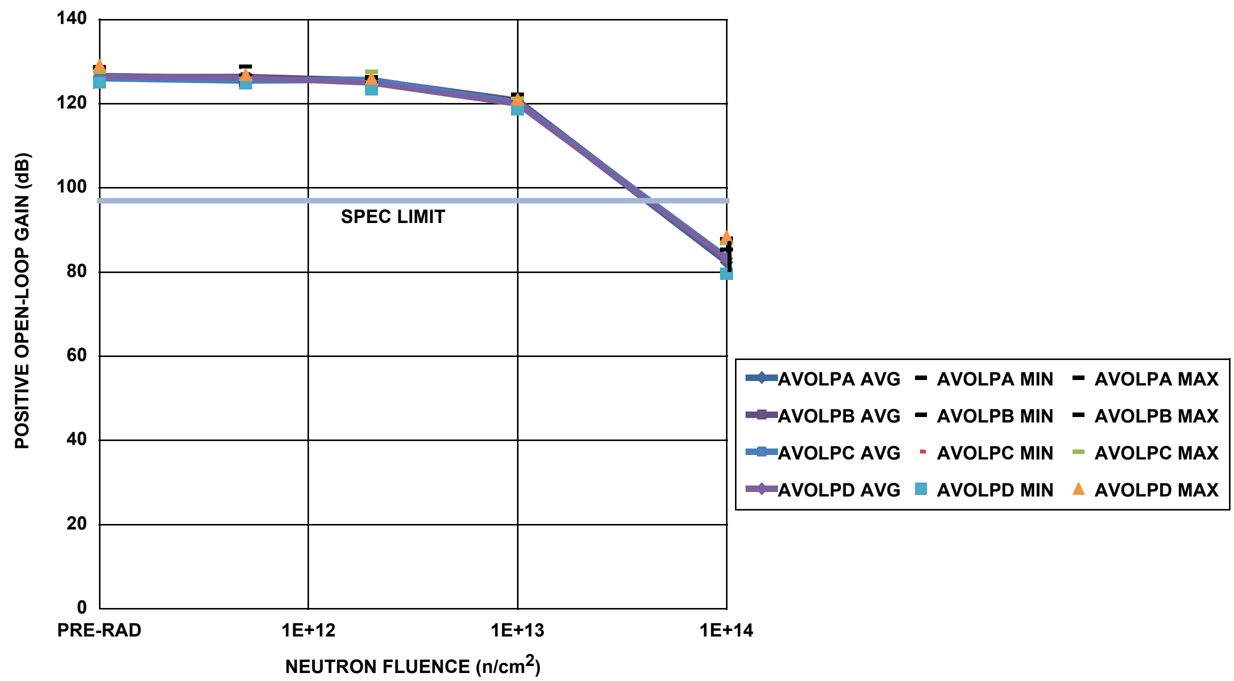

FIGURE 8. ISL70444SEH positive open-loop gain as a function of neutron irradiation, each channel, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limit is 96dB minimum.

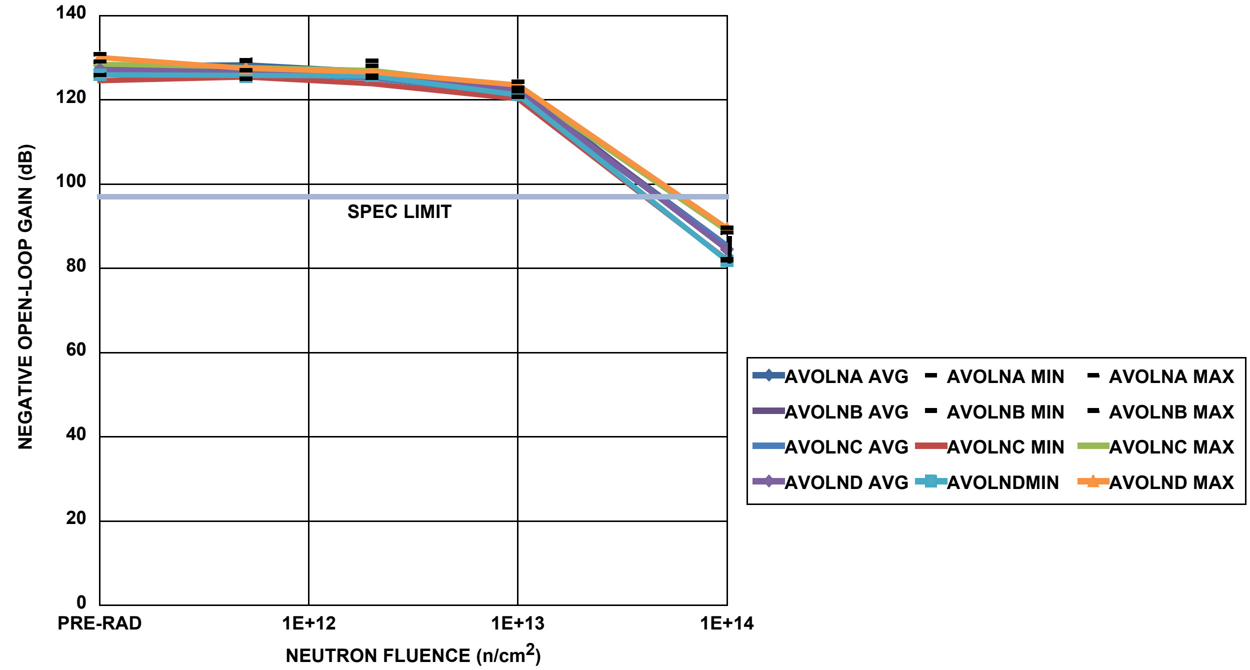

FIGURE 9. ISL70444SEH negative open-loop gain as a function of neutron irradiation, each channel, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limit is 96dB minimum.

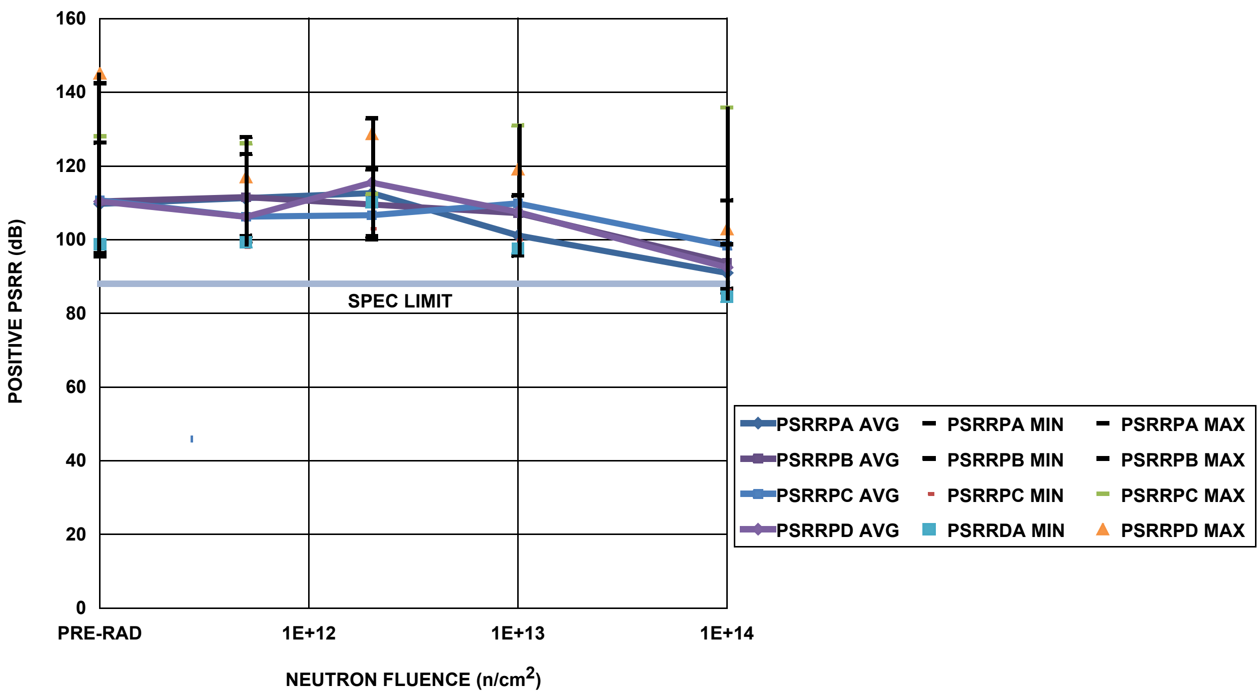

FIGURE 10. ISL70444SEH positive power supply rejection ratio as a function of neutron irradiation, each channel, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limit is 88dB minimum.

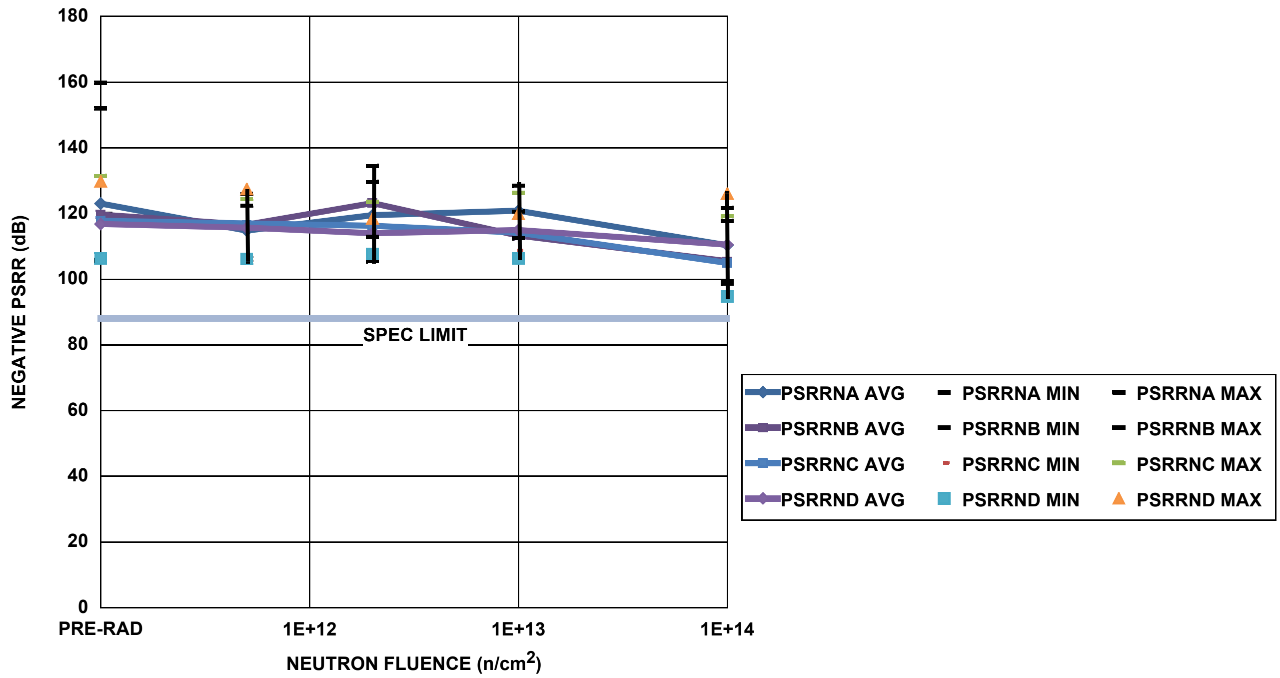

FIGURE 11. ISL70444SEH negative power supply rejection ratio as a function of neutron irradiation, each channel, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limit is 88dB minimum.

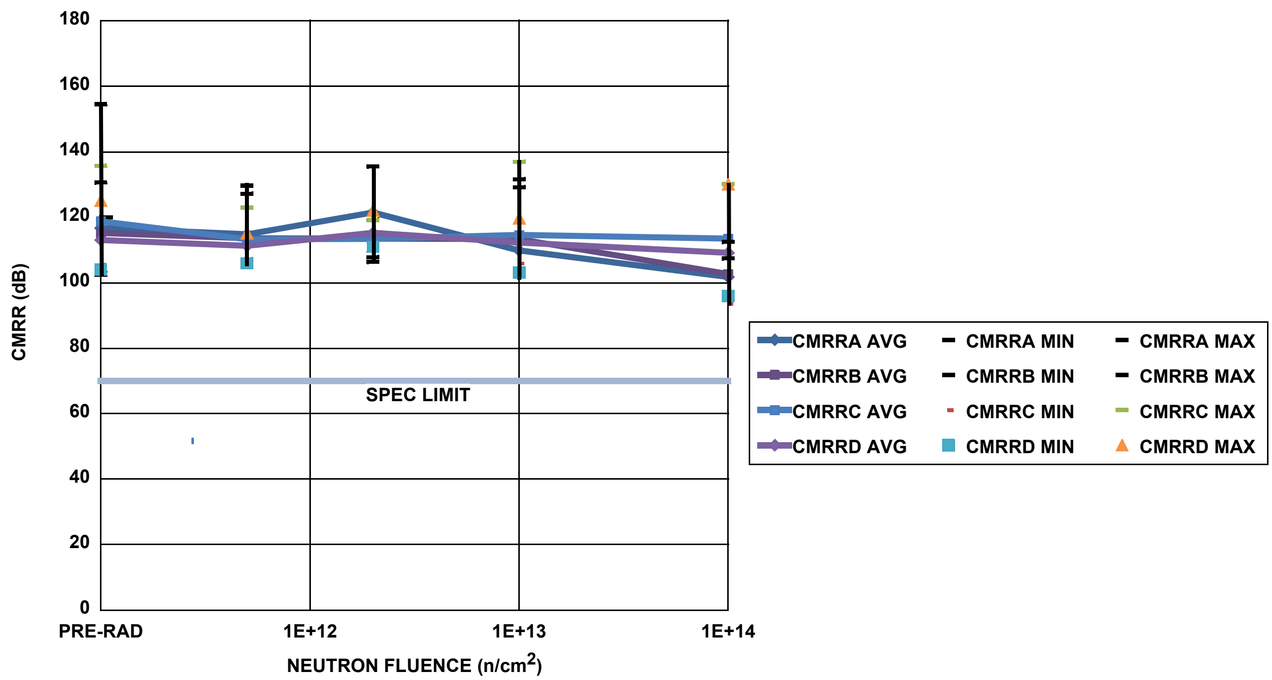

FIGURE 12. ISL70444SEH common mode rejection ratio as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell ($5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$), with two control units. The post-total dose irradiation SMD limit is 70dB minimum.

Discussion and Conclusion

This document reports the results of neutron testing of the ISL70444SEH quad operational amplifier. Samples were irradiated to levels of $5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$ with a sample size of five parts per cell. It should again be carefully realized when interpreting the attributes and variables data that each neutron irradiation was performed on a different 5-unit 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 12. The 2×10^{12} n/cm^2 level is of some interest in the context of recent developments in the JEDEC community, where the discrete component vendor community have signed up for characterization testing (but not for acceptance testing) at this level.

The ISL70444SEH is not formally designed for neutron hardness. The part is built in a DI complementary bipolar process. These bipolar transistors are minority carrier devices, obviously, and may be expected to be sensitive to Displacement Damage (DD) at the higher 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 positive power supply current (Figure 1) showed good stability after $5x10^{11}n/cm^2$ and $2x10^{12}n/cm^2$, decreased slightly after $1x10^{13}$ n/cm^2 irradiation and was down to maybe 1mA per channel after $1x10^{14}n/cm^2$ irradiation. This response indicates a gradual reduction of the operating currents as the transistor current gain degrades.

The input offset voltage (Figure 2) showed good stability at all levels but was out of specification after $1x10^{14}n/cm^2$ irradiation. The range also increased greatly at this high level.

The positive and negative input bias current (Figures 3 and 4) showed good stability at all levels and remained within the SMD post total dose specification even after $1x10^{14}n/cm^2$ irradiation. The range also increased slightly at this highest level. These results are consistent with gain degradation of the input differential pair of the amplifier.

The input offset current (Figure 5) is essentially the difference between two large numbers (specifically, the positive and negative input bias current values) and showed significant variation. It was found to be outside of the SMD total dose specification after both $1x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$ irradiation. The range was also increased considerably at the highest neutron level. These results are also consistent with gain degradation of the input differential pair of the comparator, but show good gain matching of both transistors over irradiation.

The output HIGH and LOW voltages (Figures 6 and 7) showed good stability after $5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$ and $1x10^{13}n/cm^2$ irradiation but increased significantly after $1x10^{14}n/cm^2$ irradiation. The range was also increased at this highest level. This is a key parameter in a rail-to-rail op amp, as it quantifies how close to the positive and negative rails the amplifier can swing; it has little to do with the output HIGH and LOW voltages found specified for digital parts.

The positive and negative open-loop gain (Figures 8 and 9) showed good stability after 5×10^{11} n/cm^2, 2×10^{12} n/cm^2 and 1×10^{13} n/cm^2 irradiation but decreased significantly after 1×10^{14} n/cm^2 irradiation.

The positive and negative power supply rejection ratio (Figures 10 and 11) showed good stability after $5x10^{11}n/cm^2$, $2x10^{12}n/cm^2$ and $1x10^{13}n/cm^2$ irradiation but decreased significantly after $1x10^{14}n/cm^2$ irradiation.

The common mode rejection ratio (Figure 12) showed good stability at all levels.

We conclude that the ISL70444SEH 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 parameters such as input offset voltage, input offset current and open-loop gain were well outside the SMD limits. The part did, however, remain functional. Note that AC performance data was not taken, but the large signal AC parameters such as slew rate and bandwidth were found to be within specification to $1x10^{13}n/cm^2$ in other parts using the PR40 process.

Appendices

TABLE 1. REPORTED PARAMETERS

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNIT	NOTES
1	Positive and negative power supply current	-	+9.6	mA	4 channels
2	Input offset voltage	-400.0	400.0	µV	Each channel
3	Positive input bias current	+650.0	-650.0	nA	Each channel
4	Negative input bias current	+650.0	-650.0	nA	Each channel
5	Input offset current	-17.0	+17.0	nA	Each channel
6	Output HIGH voltage	-	+160.0	mV	Each channel
7	Output LOW voltage	-	+160.0	mV	Each channel
8	Positive open loop gain	+96.0	-	dB	Each channel
9	Negative open loop gain	+96.0	-	dB	Each channel
10	Positive power supply rejection ratio	-	88.0	dB	Each channel
11	Negative power supply rejection ratio	-	88.0	dB	Each channel
12	Common mode rejection ratio	-	80.0	dB	Each channel

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