Neutron testing of the ISL7119RH hardened dual comparator

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Revision 0

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1. Introduction

This report summarizes results of 1 MeV equivalent neutron testing of the ISL7119RH dual comparator. The test was conducted in order to determine the sensitivity of the part to the displacement damage caused by the neutron environment. Neutron fluences ranged from 5 x 10^{11} n/cm^2 to 1 x 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.

2: Part Description

The ISL7119RH and ISL7119EH are radiation hardened, high speed, dual voltage comparators fabricated on a single monolithic chip. They are designed to operate over a wide dual supply voltage range as well as a single 5V logic supply and ground. The open collector output stage facilitates interfacing with a variety of logic devices and has the ability to drive relays and lamps at output currents up to 25mA. The ISL7119RH and ISL7119EH are fabricated on our dielectrically isolated Rad-hard Silicon Gate (RSG) process, which provides highly reliable performance in the natural space environment. Specifications for radiation hardened QML devices are controlled by the Defense Logistics Agency Land and Maritime (DLA). Detailed electrical specifications for the ISL7119RH and ISL7119EH are contained in SMD 5962-07215.

The ISL7119RH is implemented in the Intersil RSG process, which is a complementary bipolar/CMOS flow using dielectrically isolated (DI) substrates. The process is used for a range of hardened operational amplifiers and other analog and power management parts. The DI technology enables vertical NPN and PNP devices, unlike the vertical NPN/lateral PNP combination used in commercial junction isolated processes. The vertical PNP device improves AC performance and total dose hardness, while the DI substrate eliminates latchup by either electrical or SEE conditions. The process is in volume production under MIL-PRF-38535 certification in the Palm Bay, Florida Intersil wafer fabrication facility.

3: Test Description

3.1 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 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 Palm Bay for electrical testing.

3.2 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.

3.3 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. Three control units were used.

4: Results

4.1 Test results

Neutron testing of the ISL7119RH 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.

4.2 Variables data

The plots in Figs. 1 through 20 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 two channels as a function of neutron irradiation.

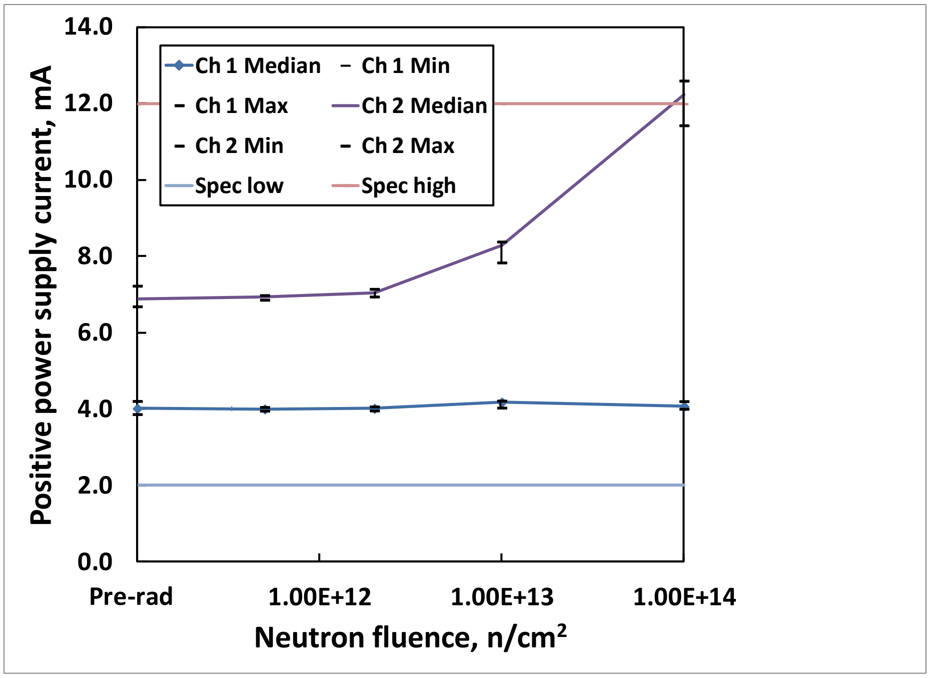

Fig. 1: ISL7119RH positive power supply current as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 12.0mA; the 2.0mA value is an ATE limit.

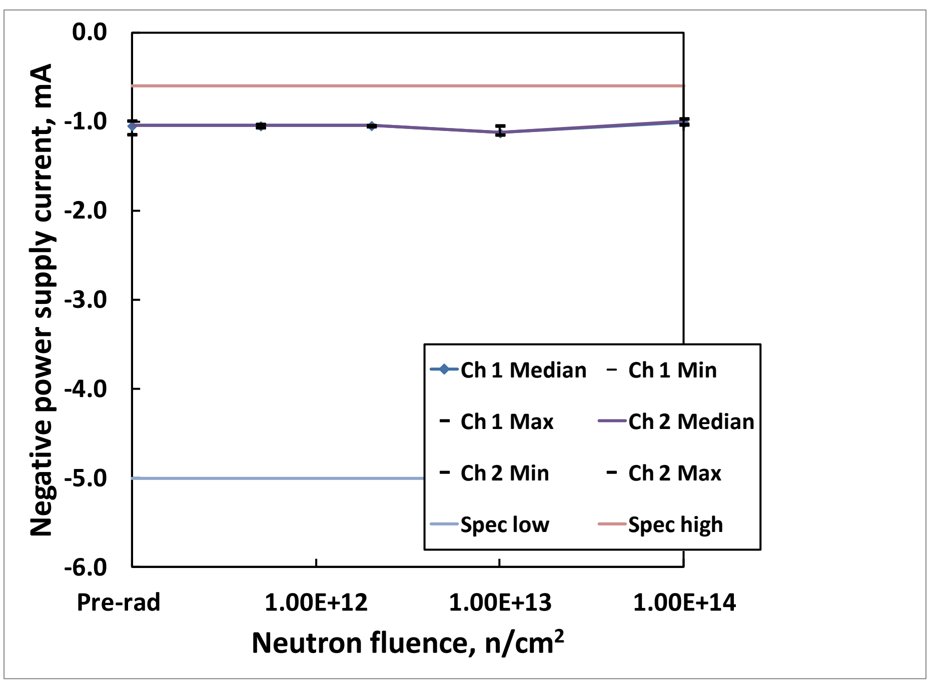

Fig. 2: ISL7119RH negative power supply current as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is -5.0.0mA; the -0.6mA value is an ATE limit.

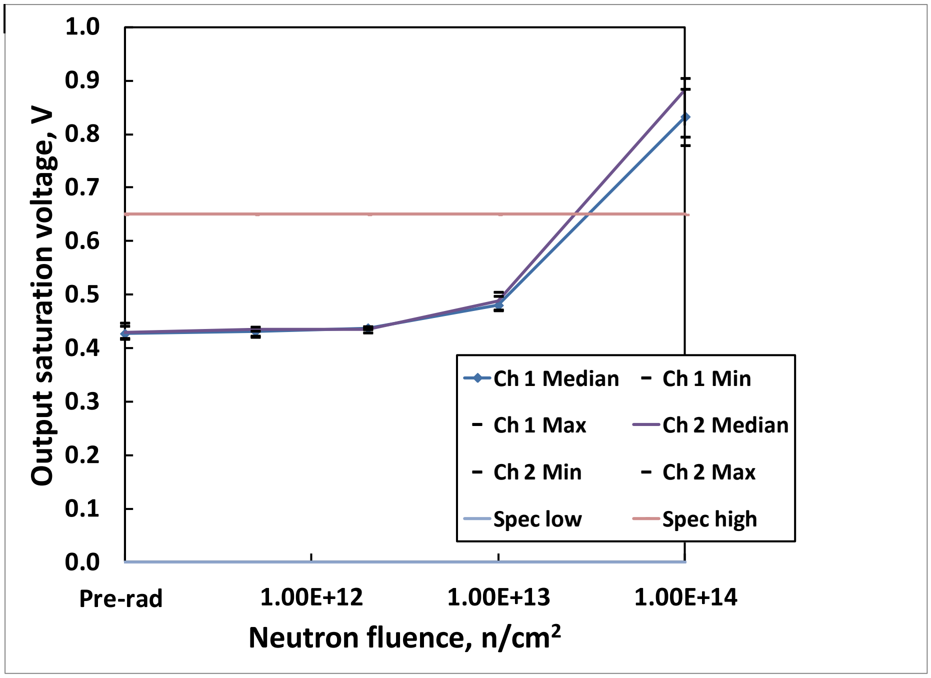

Fig. 3: ISL7119RH output saturation voltage as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 0.65V maximum.

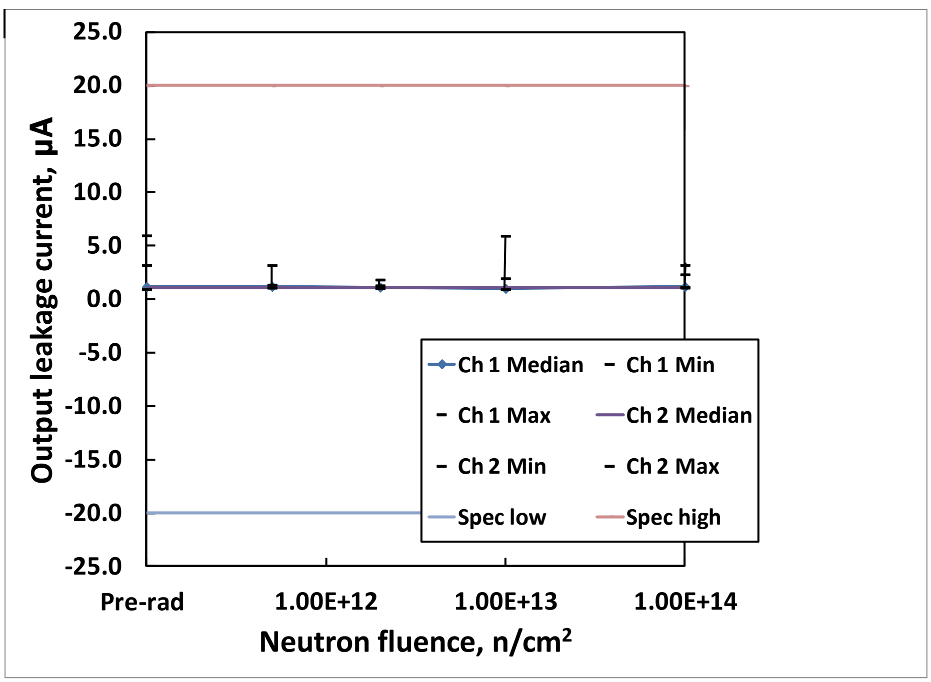

Fig. 4: ISL7119RH output leakage current as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limits are -20.0µA to 20.0µA.

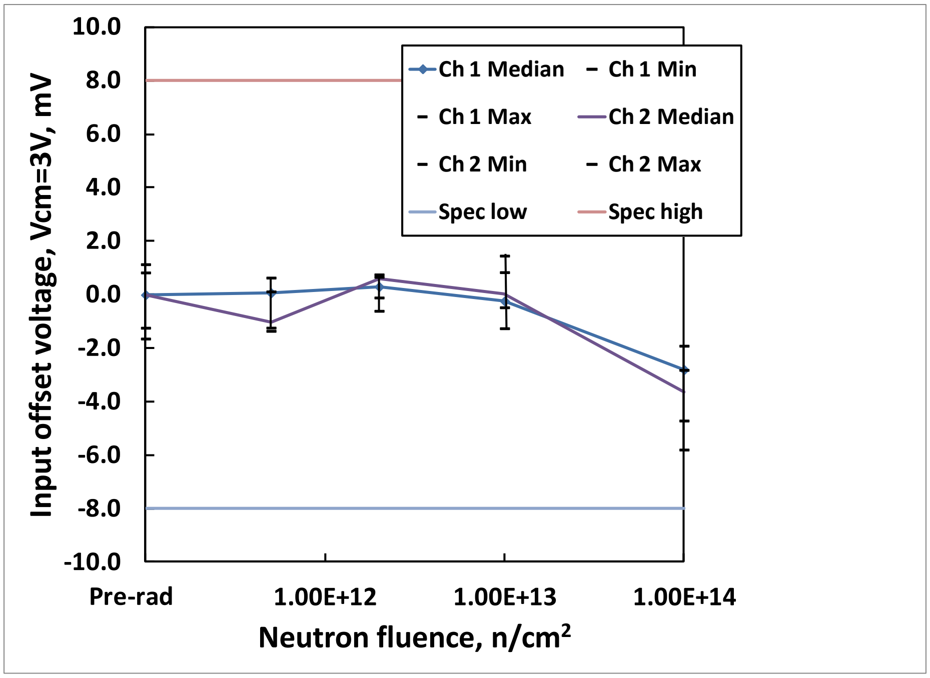

Fig. 5: ISL7119RH input offset voltage as a function of neutron irradiation, common mode voltage 3.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limits are -8.0mV to 8.0mV.

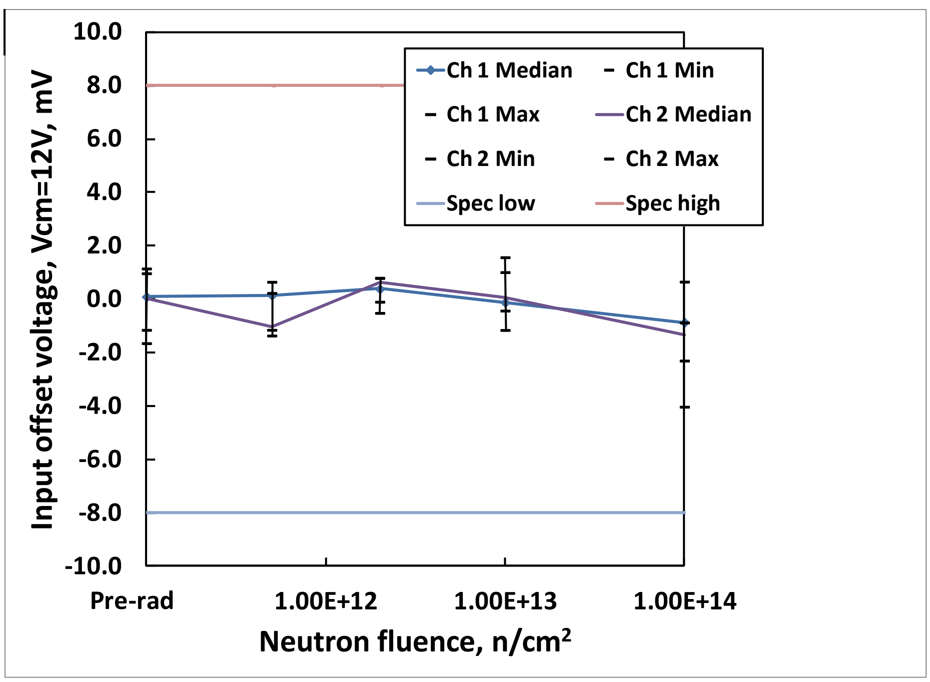

Fig. 6: ISL7119RH input offset voltage as a function of neutron irradiation, common mode voltage 12.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limits are -8.0mV to 8.0mV.

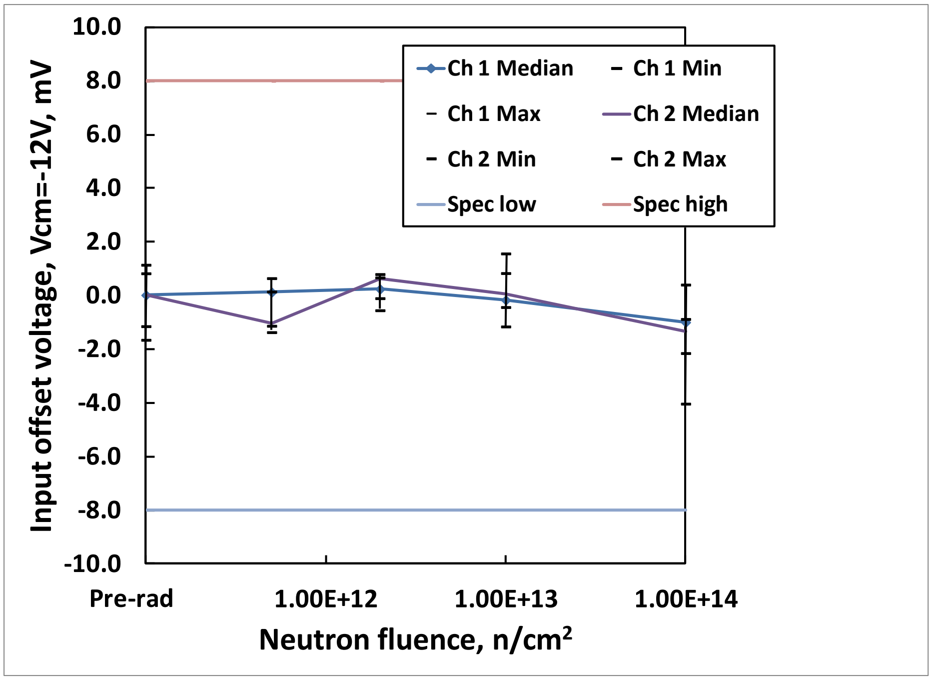

Fig. 7: ISL7119RH input offset voltage as a function of neutron irradiation, common mode voltage -12.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limits are -8.0mV to 8.0mV.

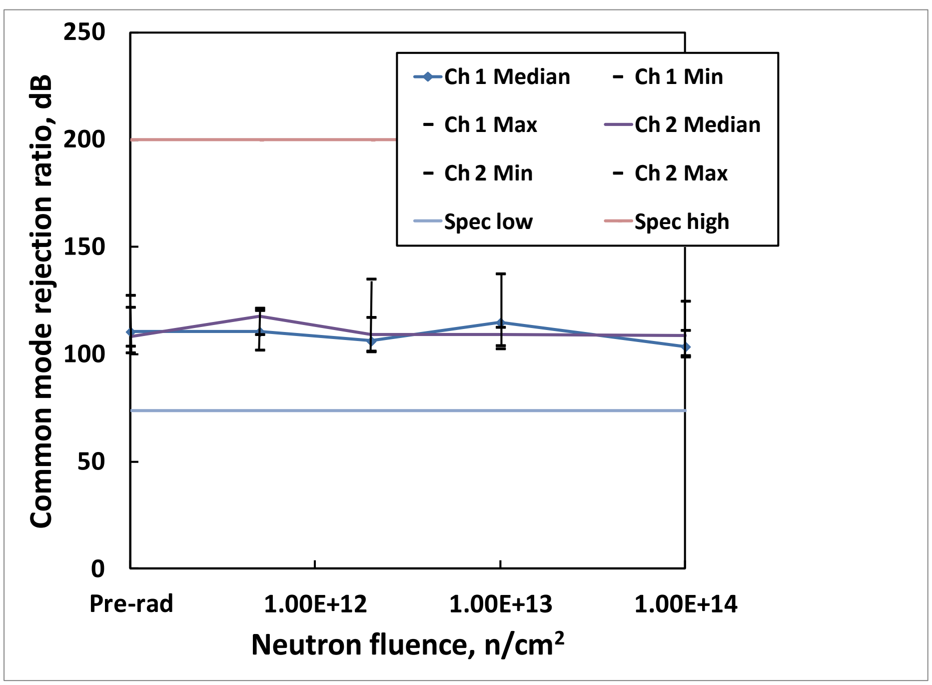

Fig. 8: ISL7119RH common mode rejection ratio as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with two control units. The post-irradiation SMD limits are 80dB to 200dB.

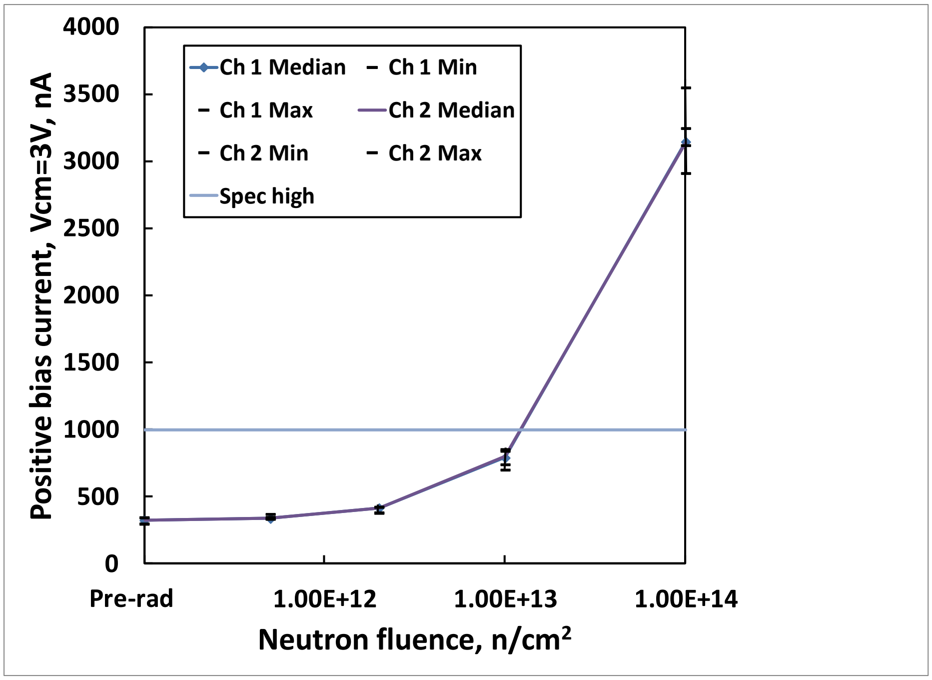

Fig. 9: ISL7119RH positive bias current as a function of neutron irradiation, common mode voltage 3.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 1000nA maximum.

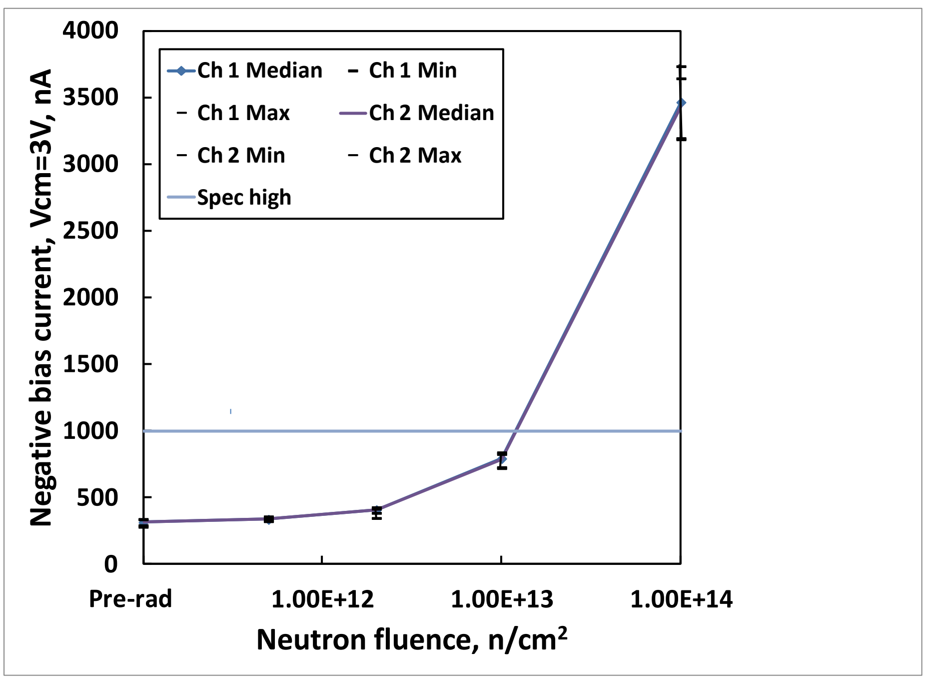

Fig. 10: ISL7119RH negative bias current as a function of neutron irradiation, common mode voltage 3.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 1000nA maximum.

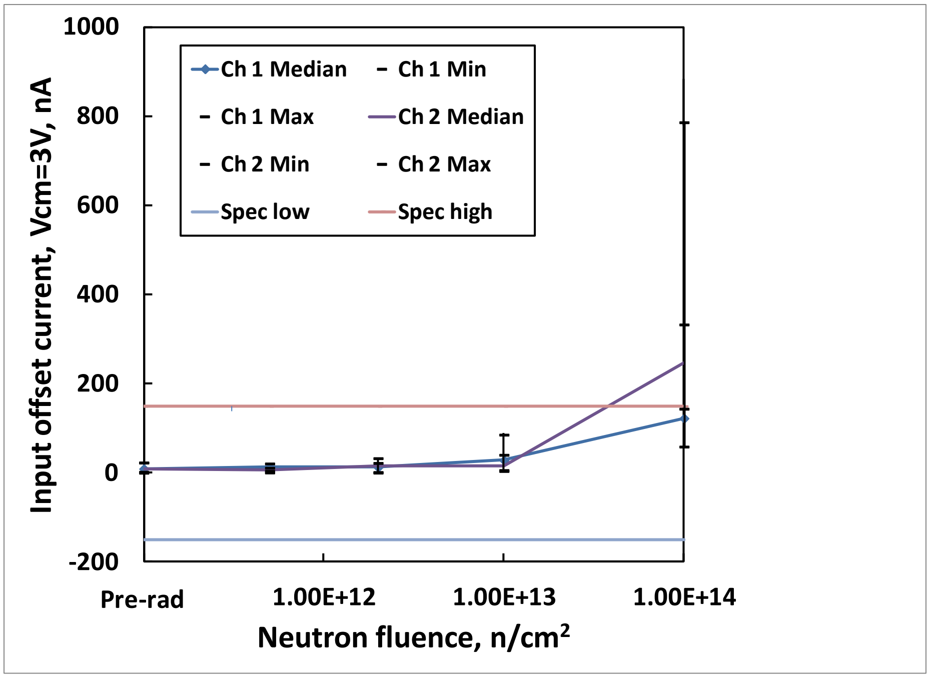

Fig. 11: ISL7119RH input offset current as a function of neutron irradiation, common mode voltage 3.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5×10^{11} n/cm^2, 2×10^{12} n/cm^2, 1×10^{13} n/cm^2 and 1×10^{14} n/cm^2), with three control units. The post-irradiation SMD limits are -150nA to 150nA.

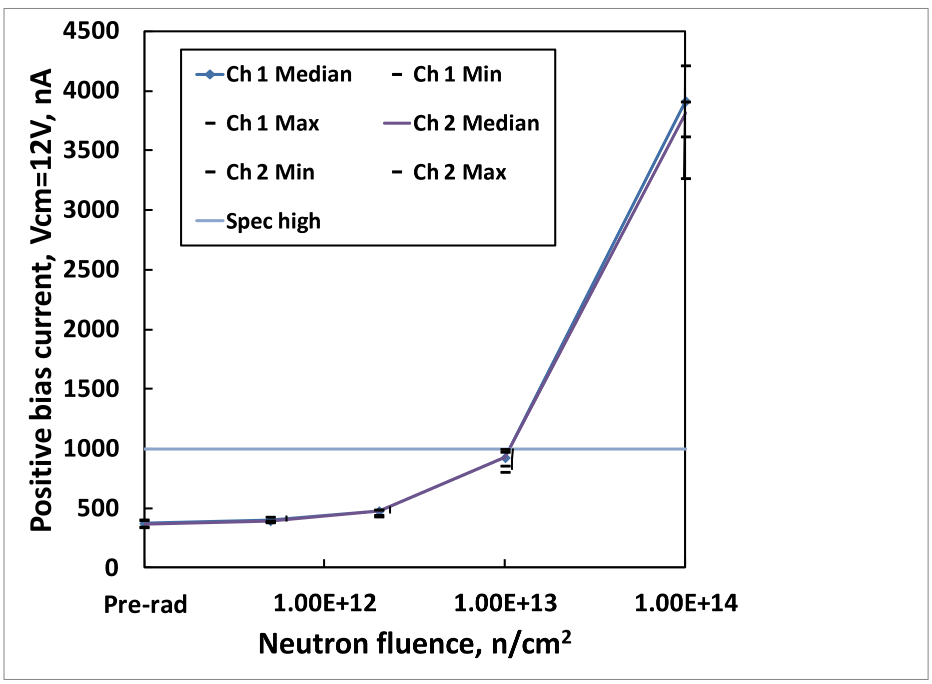

Fig. 12: ISL7119RH positive bias current as a function of neutron irradiation, common mode voltage 12.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5×10^{11} n/cm^2, 2×10^{12} n/cm^2, 1×10^{13} n/cm^2 and 1×10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 1000nA maximum.

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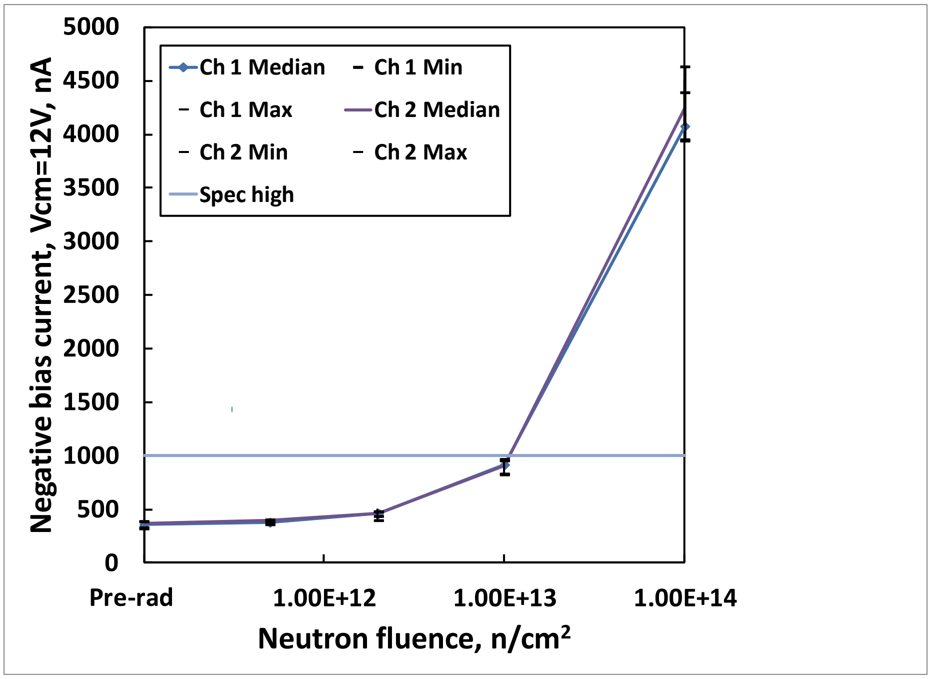

Fig. 13: ISL7119RH negative bias current as a function of neutron irradiation, common mode voltage 12.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 1000nA maximum.

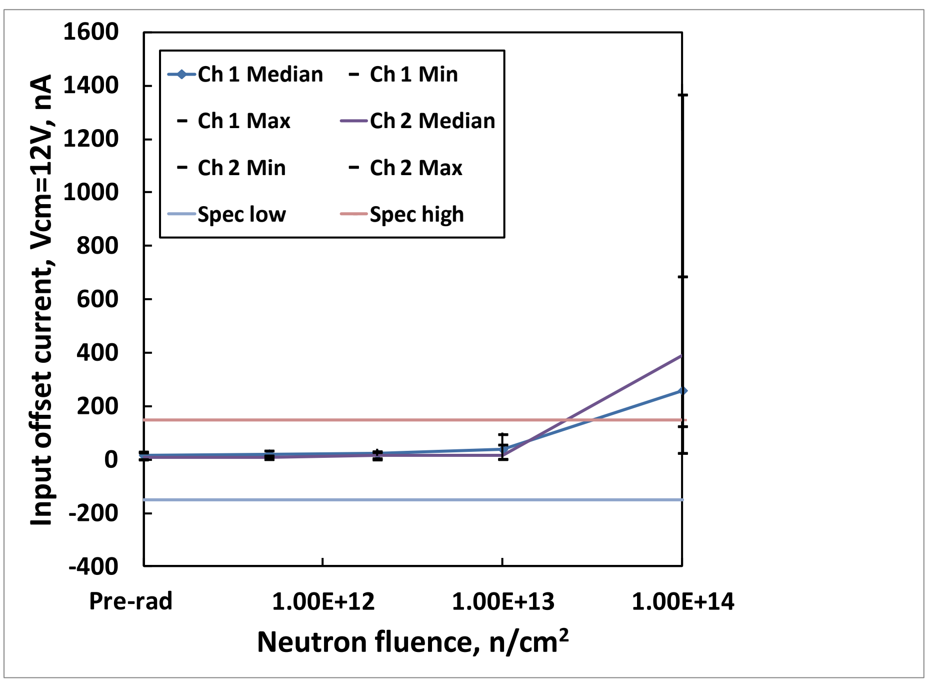

Fig. 14: ISL7119RH input offset current as a function of neutron irradiation, common mode voltage 12.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limits are -150nA to 150nA.

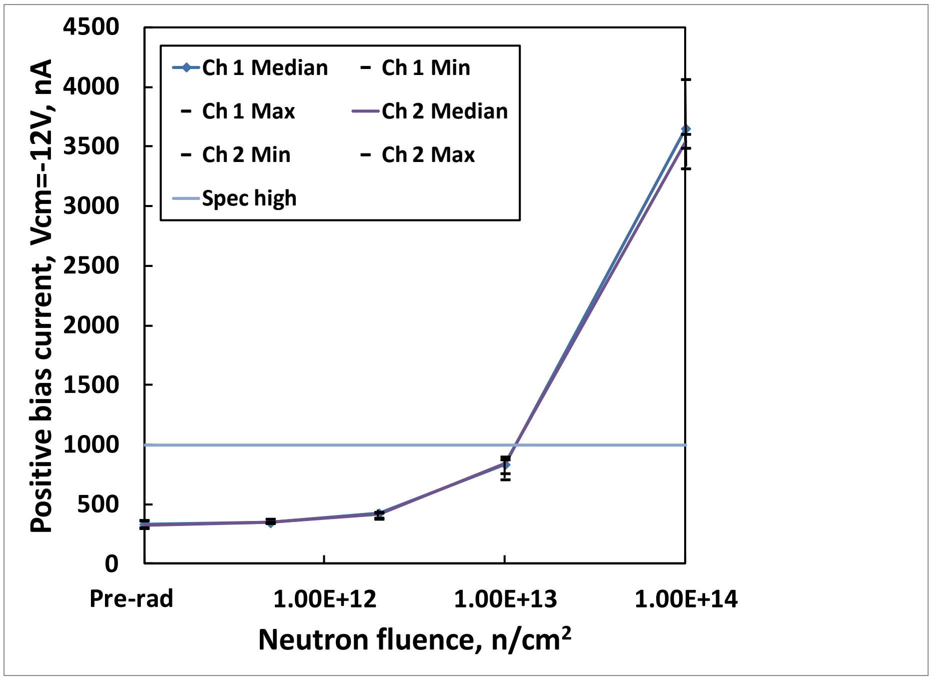

Fig. 15: ISL7119RH positive bias current as a function of neutron irradiation, common mode voltage -12.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 1000nA maximum.

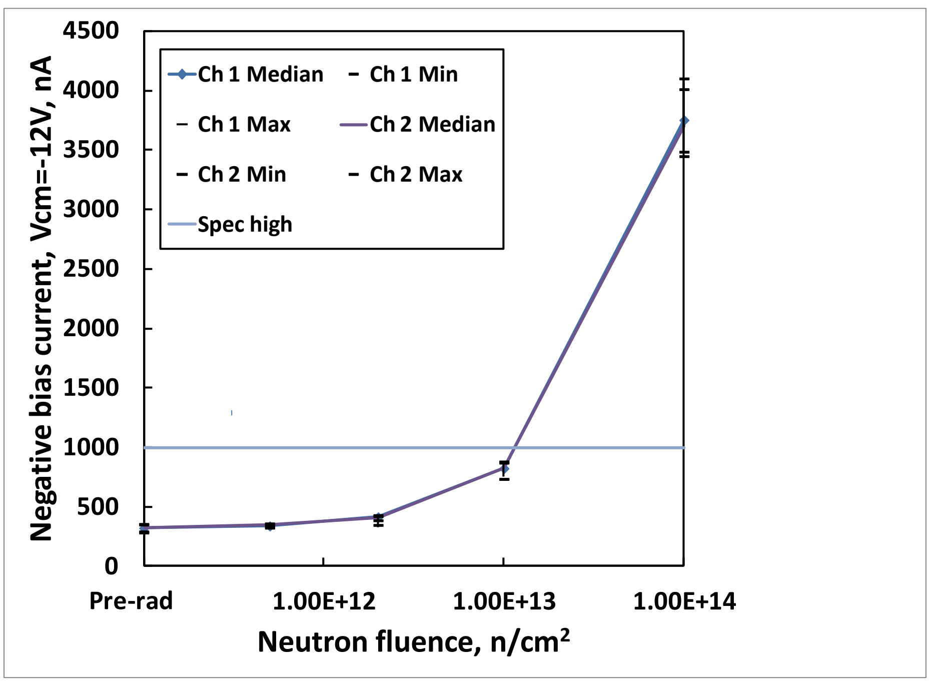

Fig. 16: ISL7119RH negative bias current as a function of neutron irradiation, common mode voltage -12.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 1000nA maximum.

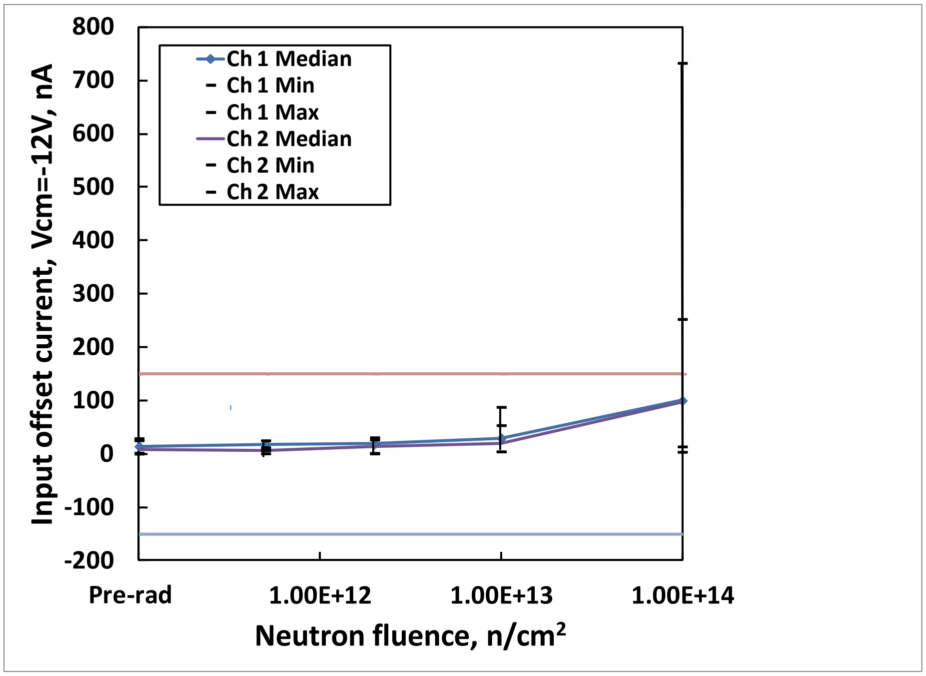

Fig. 17: ISL7119RH input offset current as a function of neutron irradiation, common mode voltage -12.0V, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limits are -150nA to 150nA.

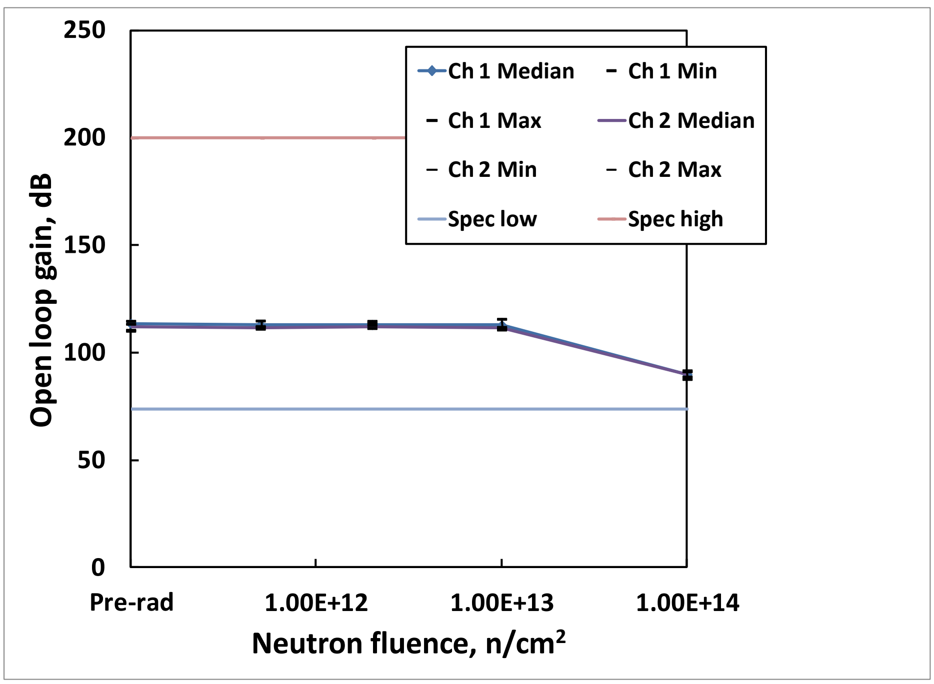

Fig. 18: ISL7119RH open-loop gain as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 74dB minimum; the 200dB value is an ATE limit.

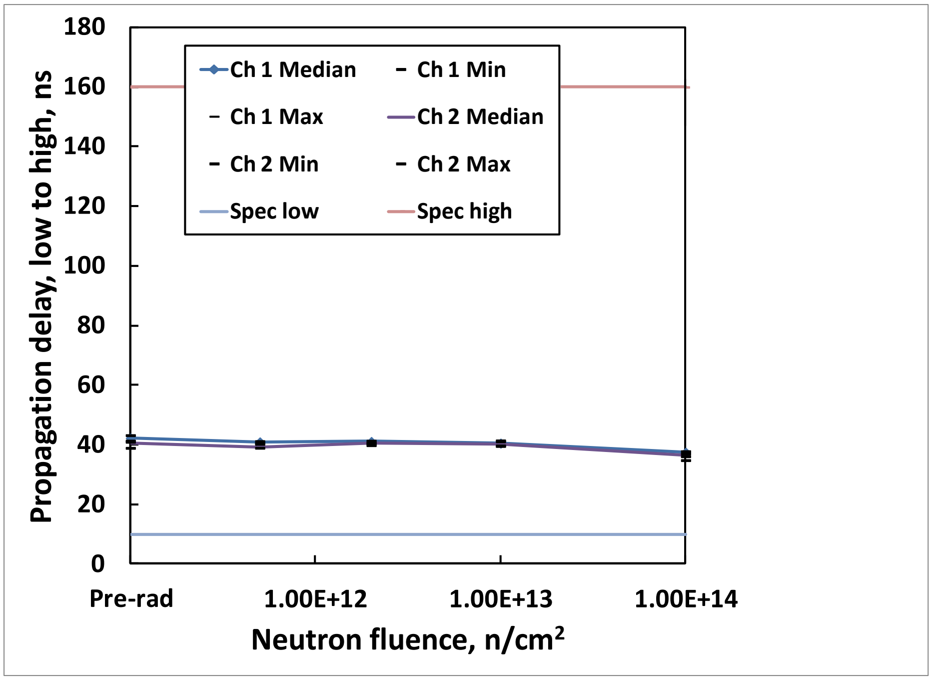

Fig. 19: ISL7119RH low to high propagation delay as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5×10^{11} n/cm^2, 2×10^{12} n/cm^2, 1×10^{13} n/cm^2 and 1×10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 160ns maximum; the 10ns value is an ATE limit.

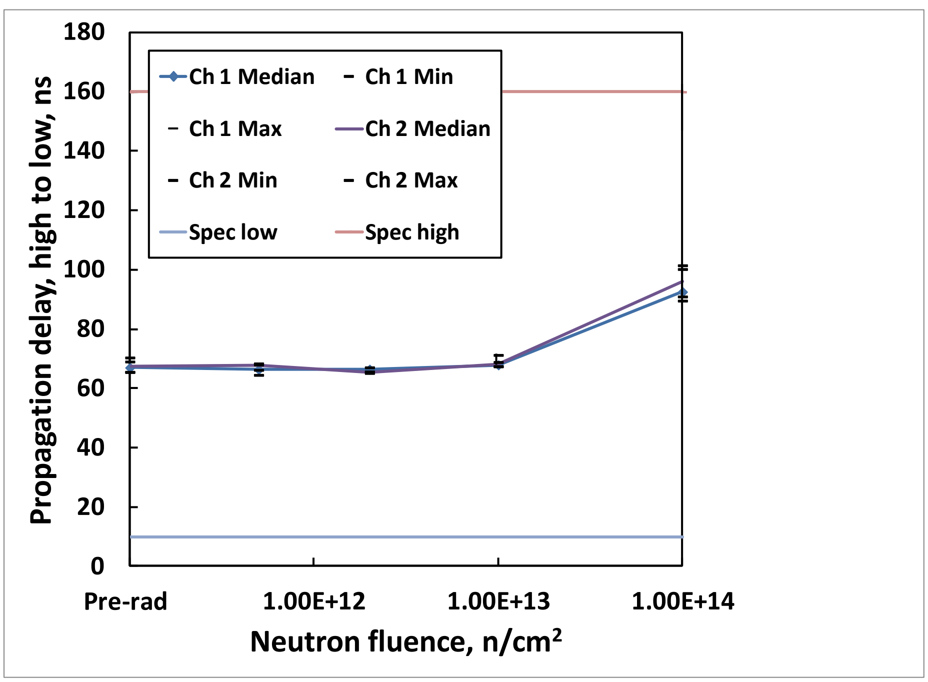

Fig. 20: ISL7119RH high to low propagation delay as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (5×10^{11} n/cm^2, 2×10^{12} n/cm^2, 1×10^{13} n/cm^2 and 1×10^{14} n/cm^2), with three control units. The post-irradiation SMD limit is 160ns maximum; the 10ns value is an ATE limit.

5: Discussion and conclusion

This document reports the results of neutron testing of the ISL7119RH dual comparator. Samples were irradiated to levels of 5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2 with a sample size of five parts per cell. It should again 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. ATE characterization testing was performed before and after the irradiations, and three control units were used to insure repeatable data. Variables data for monitored parameters is presented in Figs. 1 through 20. The 2 x 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 ISL7119RH 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 (Figs. 1 and 2) showed good stability after 5 x 10^{11} n/cm^2 and 2 x 10^{12} n/cm^2, increased after 1 x 10^{13} n/cm^2 irradiation and was out of specification after 1 x 10^{14} n/cm^2 irradiation. This behavior was observed in Channel 2 only; Channel 1 showed good stability to 1 x 10^{14} n/cm2. The reason for this channel sensitivity effect is unknown. The negative power supply current for both channels showed excellent stability to the highest level.

The output saturation voltage (Fig. 3) showed good stability after 5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2 and 1 x 10^{13} n/cm^2 irradiation but increased significantly after 1 x 10^{14} n/cm^2 irradiation. The range was also increased at this highest level.

The output leakage (Fig. 4) showed good stability at all levels, with a modest increase in range.

The input offset voltage (Figs. 5, 6 and 7) for common mode voltages of 3.0V, 12.0V and -12.0V, respectively, showed good stability at all levels.

The common mode rejection ratio (Fig. 8) showed good stability at all levels.

The positive and negative input bias current (Figs. 9 and 10) for an input common-mode voltage of 3.0V showed good stability after 5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2 and 1 x 10^{13} n/cm^2 irradiation but increased significantly after 1 x 10^{14} n/cm^2 irradiation, exceeding the post-irradiation specification limits. The range was also increased at this highest level. These results are consistent with gain degradation of the input differential pair of the comparator.

The input offset current (Fig. 11) for an input common-mode voltage of 3.0V also showed good stability after 5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2 and 1 x 10^{13} n/cm^2 irradiation but increased significantly after 1 x 10^{14} n/cm^2 irradiation. The range was also increased at this highest 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 positive and negative input bias current (Figs. 12 and 13) and the input offset current (Fig. 14) for an input common-mode voltage of 12.0V showed good stability after 5 x 10^{11} n/cm^2, 2 x 10^{12} n/cm^2 and 1 x 10^{13} n/cm^2 irradiation but increased significantly after 1 x 10^{14} n/cm^2 irradiation, exceeding the post-irradiation specification limits. The positive and negative input bias current and input offset current at a common-mode input voltage of -12.0V (Figs. 15, 16 and 17) showed similar behavior.

The open-loop gain (Fig. 18) showed good stability at all levels.

The low to high and high to low response times (Figs. 19 and 20) showed good stability at all levels.

We conclude that the ISL7119RH is capable of post 1 x 10^{13} n/cm^2 operation within the SMD post-total dose parameters. The part is not capable of post 1 x 10^{14} n/cm^2 operation as parameters such as input bias current and input offset current were well outside the SMD limits; the part did, however, remain functional.

6: Appendices

6.1: Reported parameters.

Fig.	Parameter	Limit, low	Limit, high	Units	Notes
1	Positive power supply current	-	+12.0	mA	
2	Negative power supply current	-	-5.0	mA	
3	Output saturation voltage		+0.65	V	
4	Output leakage current	-20.0	+20.0	µA	
5	Input offset voltage	-8.0	+8.0	mV	Vcm=3.0V
6	Input offset voltage	-8.0	+8.0	mV	Vcm=12.0V
7	Input offset voltage	-8.0	+8.0	mV	Vcm=-12.0V
8	Common mode rejection ratio	+80	+200	dB	
9	Positive bias current	-	+1000	nA	Vcm=3.0V
10	Negative bias current	-	+1000	nA	Vcm=3.0V
11	Input offset current	-150.0	+150.0	nA	Vcm=3.0V
12	Positive bias current	-	+1000	nA	Vcm=12.0V
13	Negative bias current	-	+1000	nA	Vcm=12.0V
14	Input offset current	-150.0	+150.0	nA	Vcm=12.0V
15	Positive bias current	-	+1000	nA	Vcm=-12.0V
16	Negative bias current	-	+1000	nA	Vcm=-12.0V
17	Input offset current	-150.0	+150.0	nA	Vcm=-12.0V
18	Open-loop gain	+74	-	dB	
19	LOW to HIGH propagation delay	-	160	ns	
20	HIGH to LOW propagation delay	-	160	ns	

7: Document revision history

Revision	Date	Pages	Comments
0	3 July 2013	All	Original issue