IS-139ASRH

1MeV Equivalent Neutron Testing of the IS139ASRH Quad Comparator

Introduction

This report summarizes results of 1MeV equivalent neutron testing of the IS-139ASRH quad comparator. 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 $2x10^{12}n/cm^2$ to $1x10^{14}n/cm^2$. This project was carried out in collaboration with Boeing (El Segundo, CA), whose support is gratefully acknowledged.

Reference Documents

- **MIL-STD-883 test method 1017**
- **IS-139ASRH datasheet**
- **DSCC Standard Microcircuit Drawing (SMD) 5962-01510**

Part Description

The IS-139ASRH is a Single Event Effects (SEE) and total dose radiation hardened quad analog comparator consisting of four independent single or dual supply comparators on a single monolithic substrate. The common-mode input voltage range includes ground, even when operated from a single supply, and the low supply current makes the part suitable for low power applications. The IS-139ASRH is designed to directly interface with TTL and CMOS inputs. The part is fabricated on the Renesas dielectrically isolated Radiation Hardened Silicon Gate (RSG) process, which provides immunity to single event latch-up.

The IS-139ASRH is acceptance tested to a Total Dose (TID) level of 300krad(Si) at high dose rate (50-300rad(Si)/s). The IS-139ASEH variant is acceptance tested to a total dose level of 300krad(Si) at high dose rate and to 50krad(Si) at low dose rate (<0.01rad(Si)/s). The IS-139ASRH uses on-chip redundancy to provide superior Single-Event Transient (SET) performance to a Linear Energy Transfer (LET) value of $86.4MeV•cm^2/mg$.

Table 1. IS-139ASRH Pin Assignments

Terminal Number	Terminal Symbol	Terminal Number	Terminal Symbol
1	NC	11	+INB
2	OUTB	12	-INC
3	NC	13	+INC
4	OUTA	14	-IND
5	NC	15	+IND
6	NC	16	NC
7	VCC	17	GND
8	-INA	18	NC
9	+INA	19	OUTD
10	-INB	20	OUTC

Specifications for Radiation Hardened QML devices are controlled by the Defense Logistics Agency Land and Maritime (DLA). Detailed electrical specifications for the IS-139ASRH and IS-139ASEH are contained in SMD 5962-01510.

Contents

1. Test Description

1.1 Irradiation Facilities

1MeV equivalent neutron irradiation was performed by the Boeing team at the White Sands Missile Range fast burst reactor. Dosimetry data can be furnished upon request. Parts were tested in an unbiased configuration with all leads shorted together in general 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 considerable ‘cooldown’ time before being shipped back to Renesas (Palm Bay, FL) for electrical testing.

1.2 Test Fixturing

No formal irradiation test fixturing was involved, as these DD tests are termed ‘bag tests’ in the sense that the parts are irradiated in an electrically inactive state with all leads shorted together.

1.3 Characterization Equipment and Procedures

Electrical testing was performed before and after irradiation using the Renesas Palm Bay, FL production Automated Test Equipment (ATE). All electrical testing was performed at room temperature.

1.4 Experimental Matrix

The experimental matrix consisted of 5 samples irradiated at $2x10^{12}n/cm^2$, 5 irradiated at $1x10^{13}n/cm^2$, 5 irradiated at $3x10^{13}n/cm^2$ and 5 irradiated at $1x10^{14}n/cm^2$. Five control units were used. IS-139ASRHF/PROTO samples were drawn from fabrication lot G2E3PBEH. Samples were packaged in the standard hermetic 20 Ld ceramic flatpack production package, code K20.A. Samples were screened to the SMD limits over temperature before the start of neutron testing.

2. Results

Neutron testing of the IS-139ASRH 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 over a number of downpoints.

2.1 Attributes Data

Table 2. IS-139ASRH Attributes Data

Part	Serial	Sample Size	Fluence n/cm^2	Pass[1]	Fail	Notes
IS-139ASRH	1-5	5	$2x10^{12}$	5	0	All passed
IS-139ASRH	6-10	5	$1x10^{13}$	1	4	Four failed parametrically, input bias current and input offset current
IS-139ASRH	11-15	5	$3x10^{13}$	0	5	Five failed parametrically, input bias current and input offset current
IS-139ASRH	16-20	5	$1x10^{14}$	0	5	All failed, nonfunctional

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

2.2 Variables Data

The plots in Figure 1 through Figure 17 show data plots for key parameters before and after irradiation to each level. The reported parameters and their datasheet limits are shown in Appendices. As indicated in Table 1 all samples were nonfunctional after exposure to $1x10^{14}n/cm^2$, and we elected to not plot the data at this level as it has little meaning and makes the data at the other three levels more difficult to interpret.

The plots show the population median of each parameter as a function of neutron irradiation as well as population maximum/minimum bars. We chose to plot the median because of the small sample sizes (five per cell) involved. We also show the applicable post-total dose electrical limits as taken from the SMD.

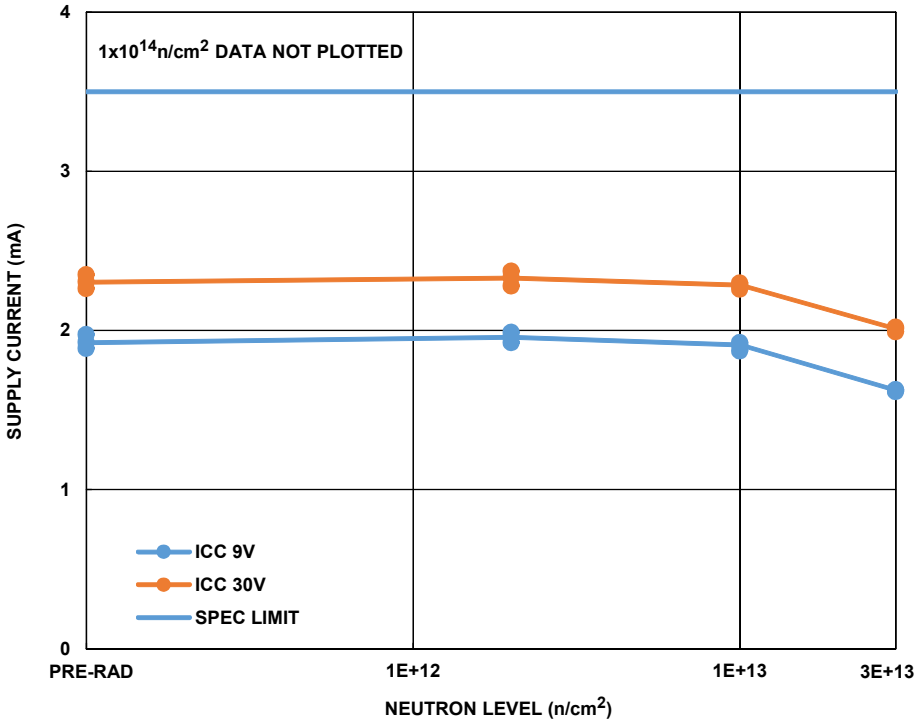

Figure 1. IS-139ASRH supply current for the 9V and 30V supply cases, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limit is 3.5mA maximum.

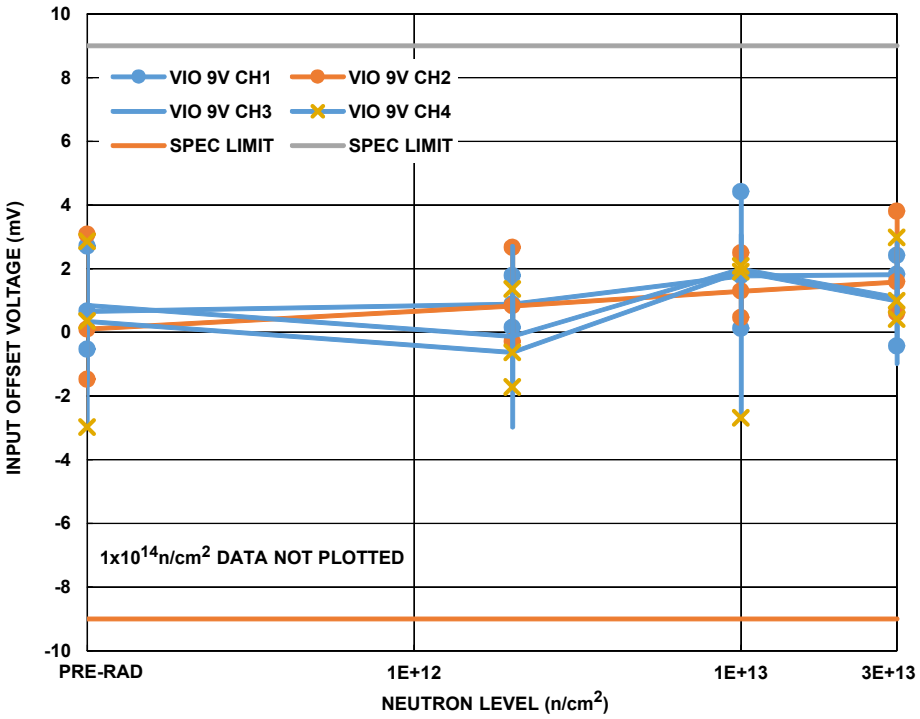

Figure 2. IS-139ASRH input offset voltage for the 9V supply case, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limits are -9mV to 9mV.

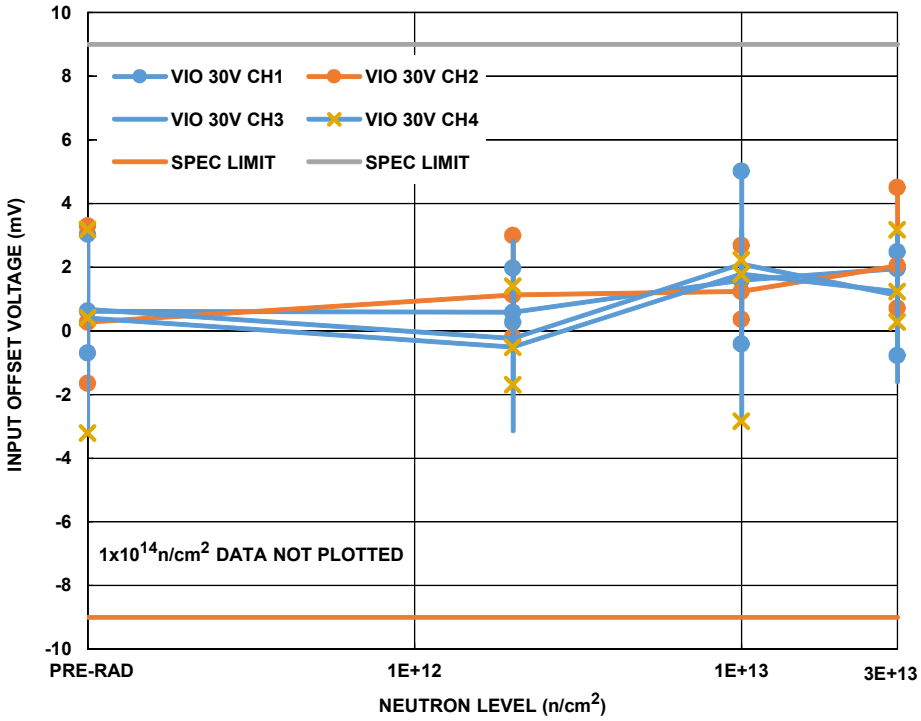

Figure 3. IS-139ASRH input offset voltage for the 30V supply case, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limits are -9mV to 9mV.

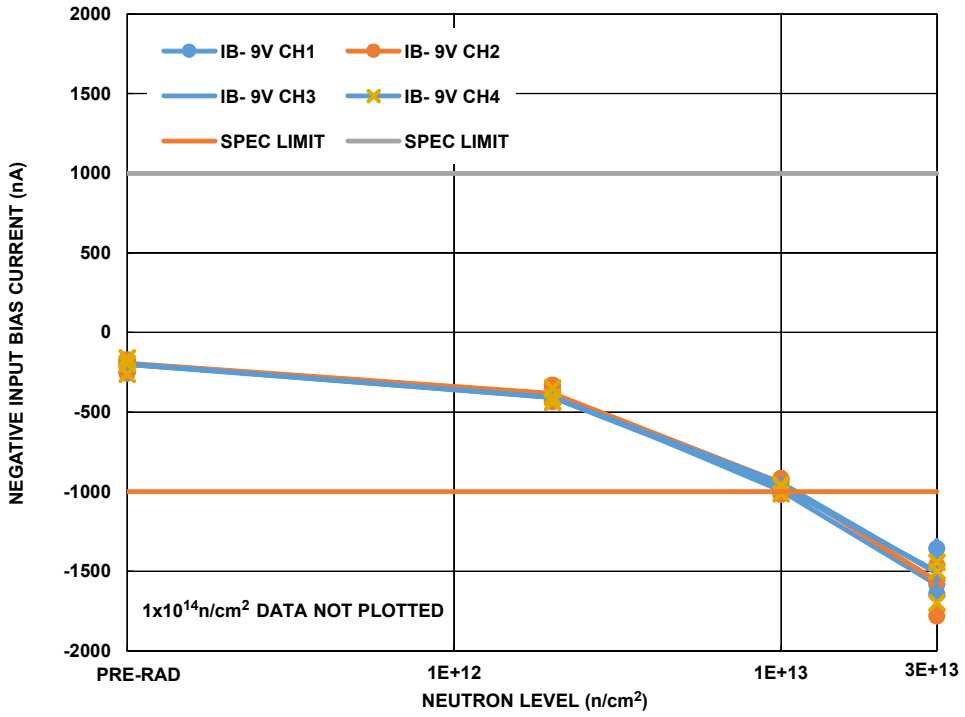

Figure 4. IS-139ASRH negative input bias current for the 9V supply case, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limits are -1000nA to 1000nA.

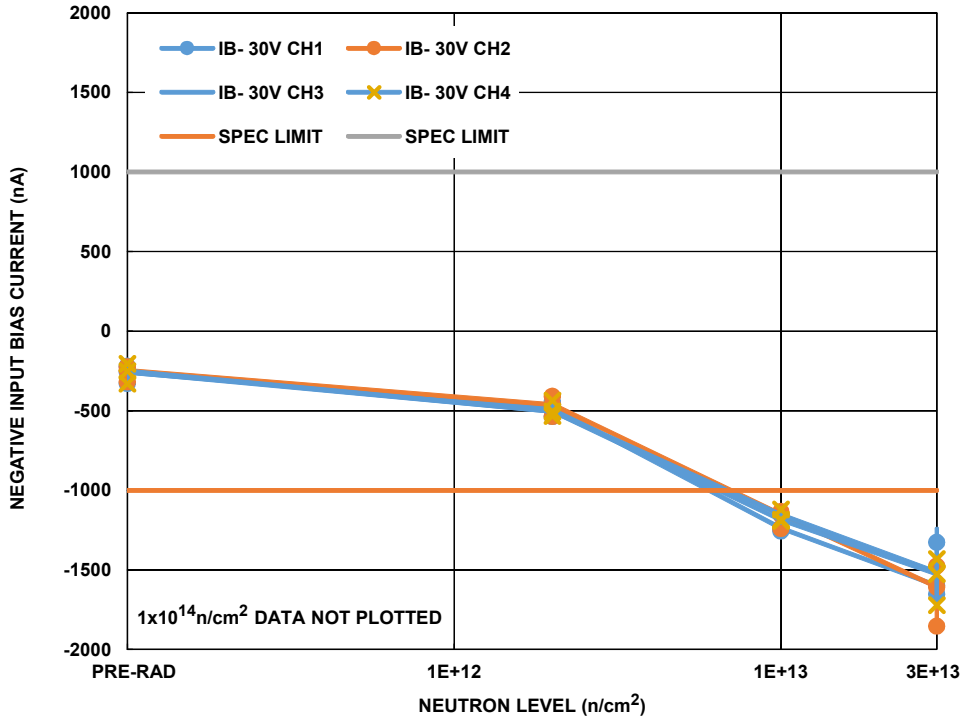

Figure 5. IS-139ASRH negative input bias current for the 30V supply case, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limits are -1000nA to 1000nA.

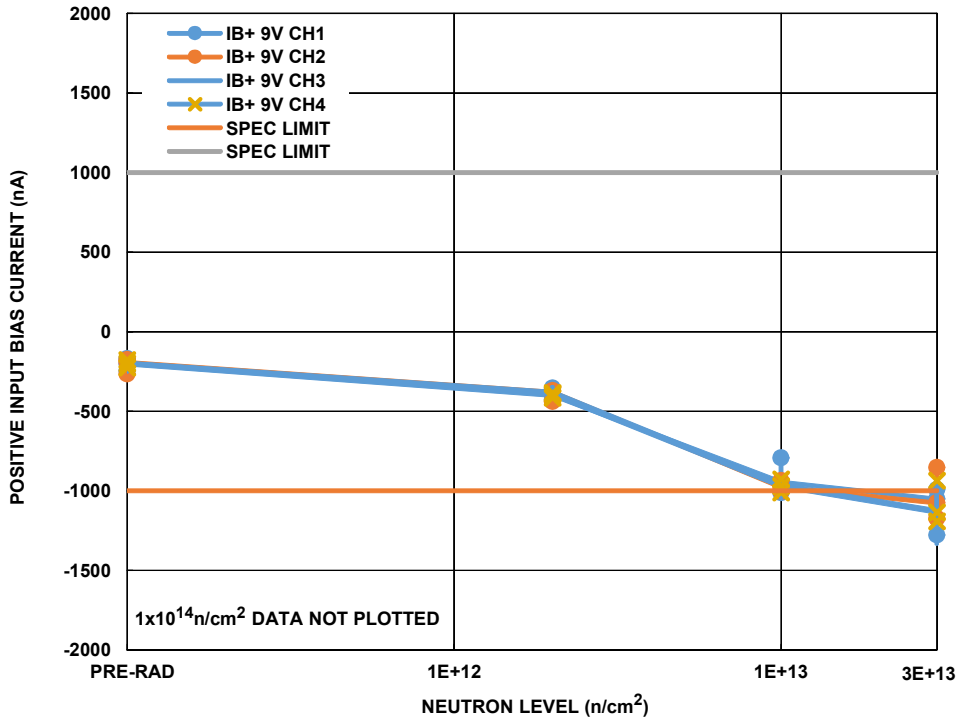

Figure 6. IS-139ASRH positive input bias current for the 9V supply case, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limits are -1000nA to 1000nA.

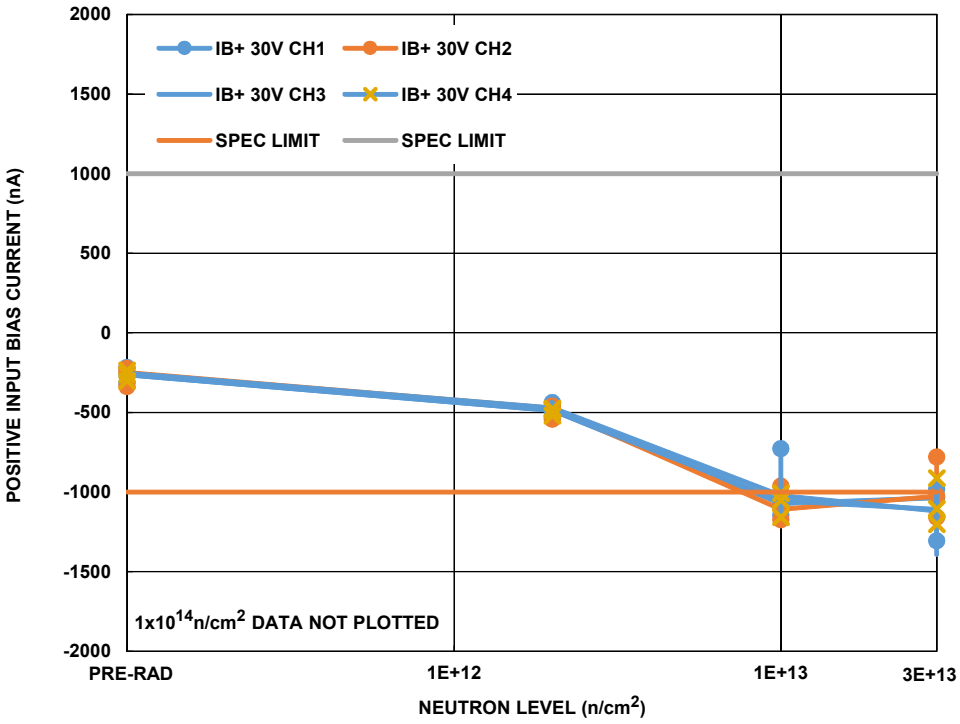

Figure 7. IS-139ASRH positive input bias current for the 30V supply case, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limits are -1000nA to 1000nA.

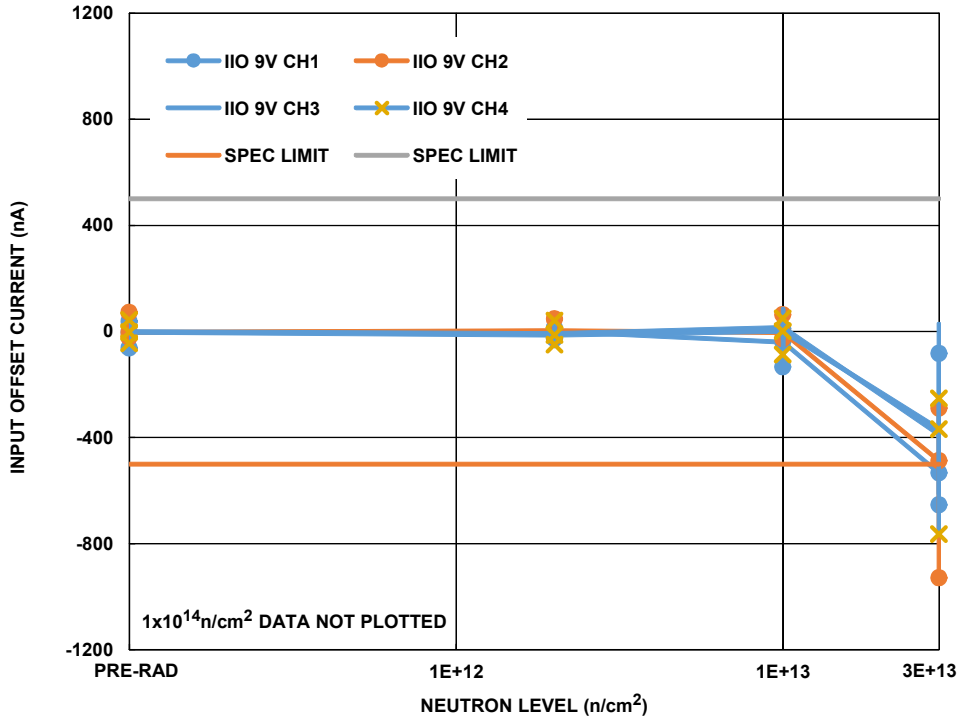

Figure 8. IS-139ASRH input offset current for the 9V supply case, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limits are -500nA to 500nA.

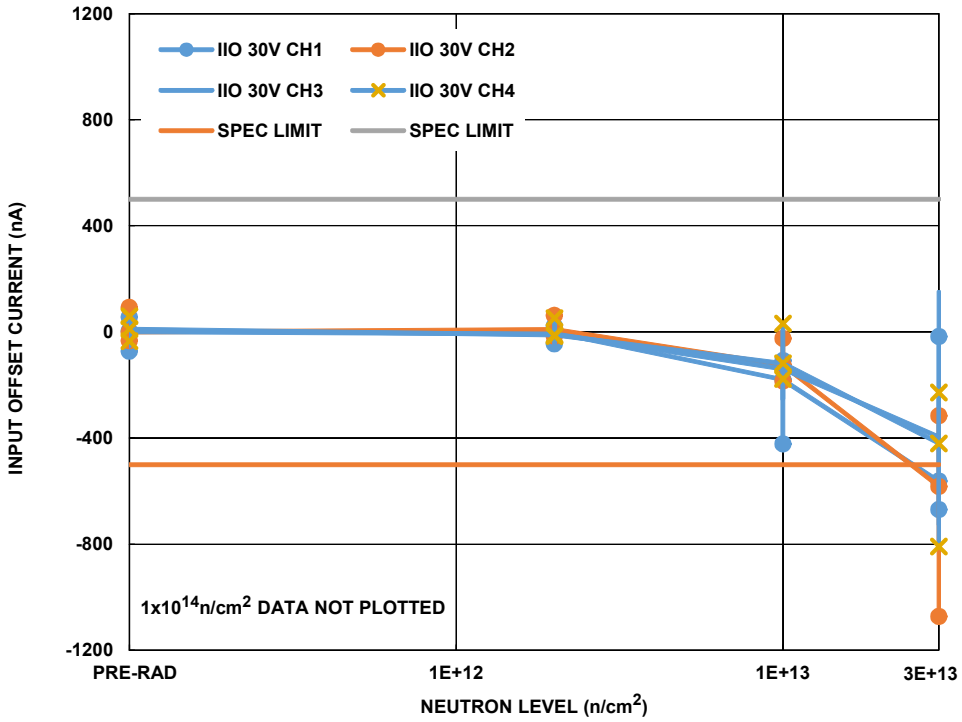

Figure 9. IS-139ASRH input offset current for the 30V supply case, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limits are -500nA to 500nA.

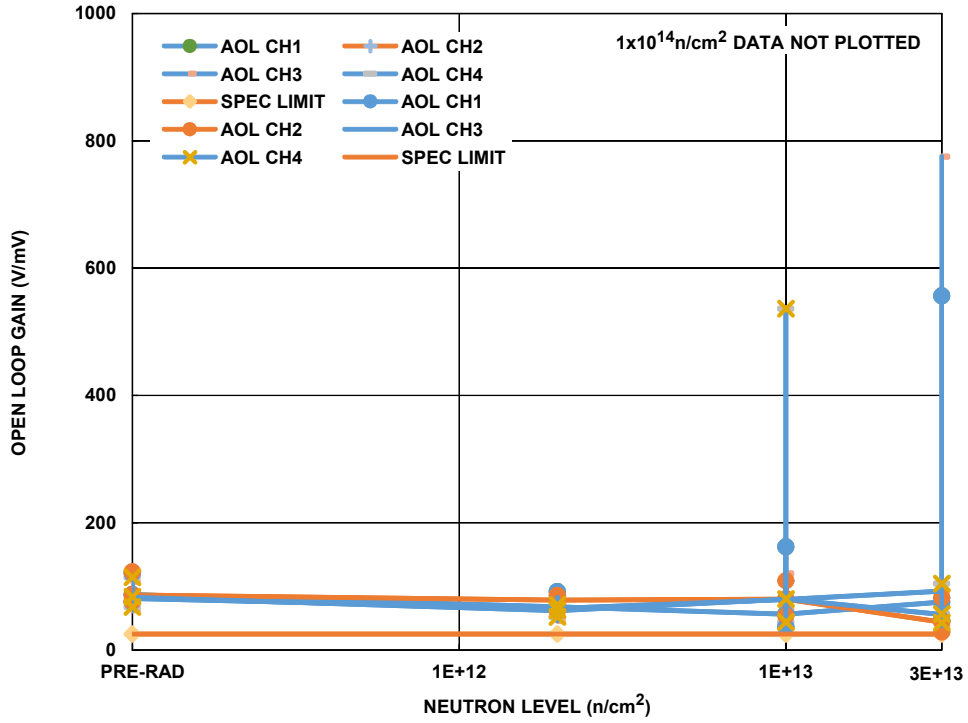

Figure 10. IS-139ASRH open loop gain, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limit is 25V/mV minimum.

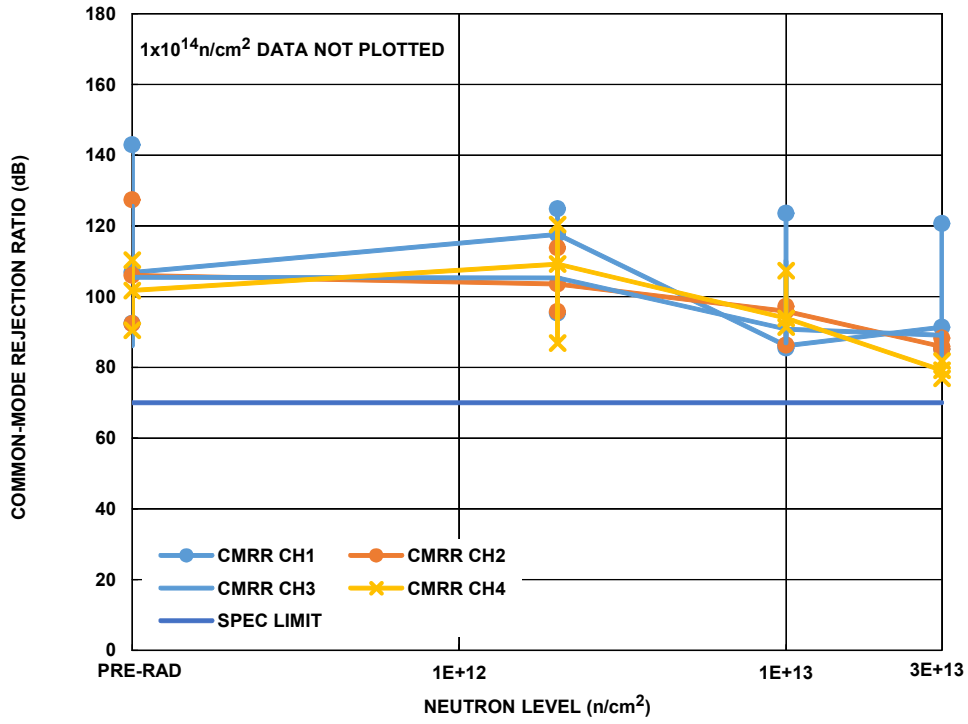

Figure 11. IS-139ASRH common-mode rejection ratio, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limit is 70dB minimum.

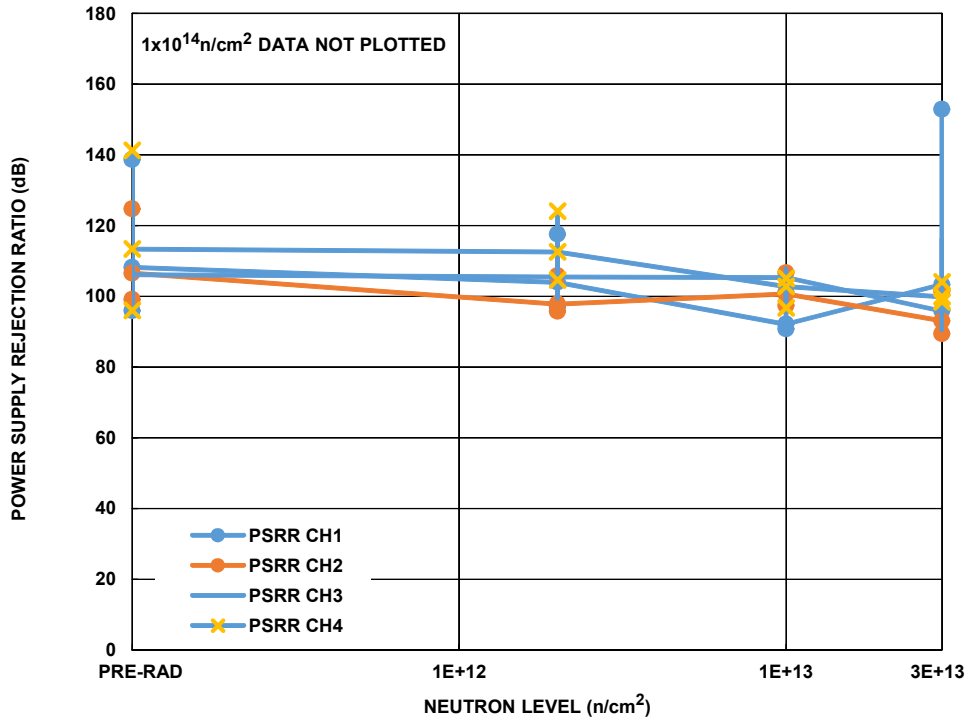

Figure 12. IS-139ASRH power supply rejection ratio, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The parameter is not specified in the SMD; for reference, the ATE limit is 60dB minimum.

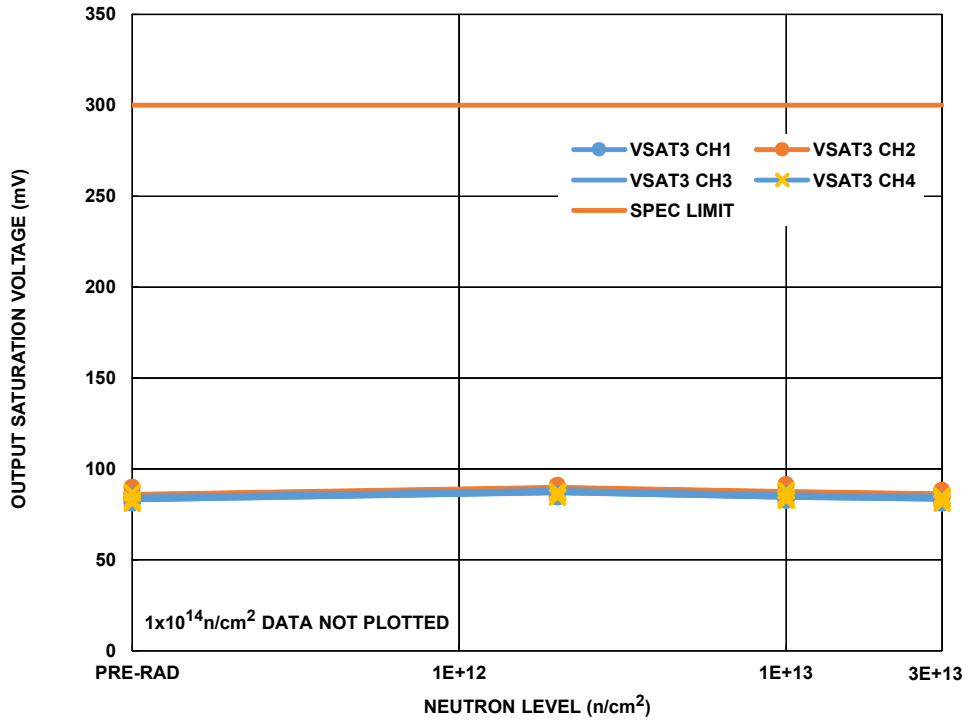

Figure 13. IS-139ASRH output saturation voltage, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limit is 300mV maximum.

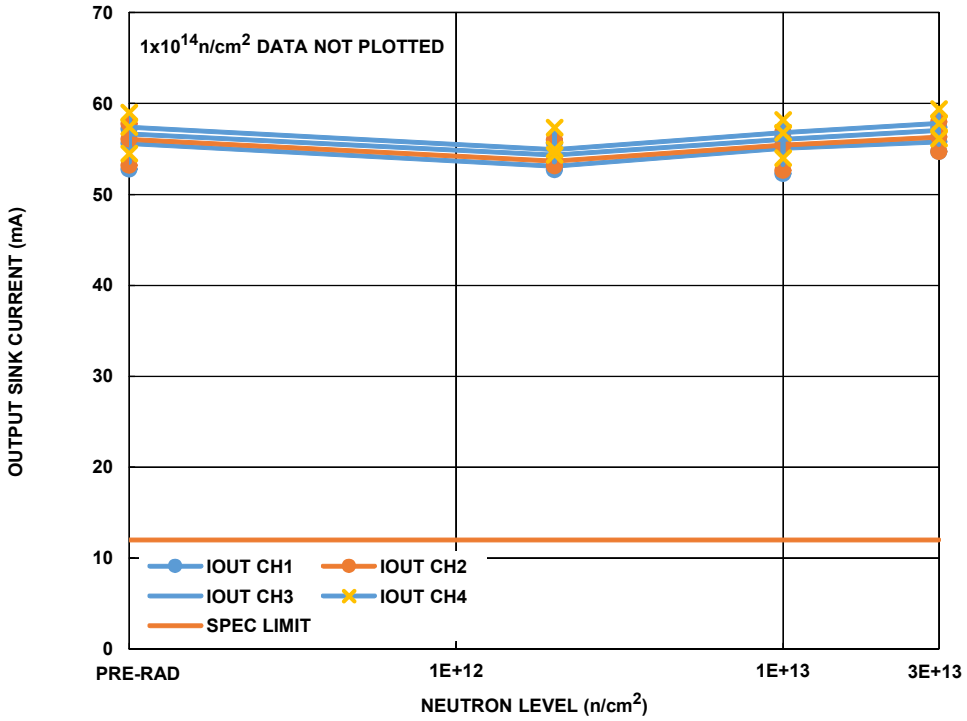

Figure 14. IS-139ASRH output sink current, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limit is 12mA minimum.

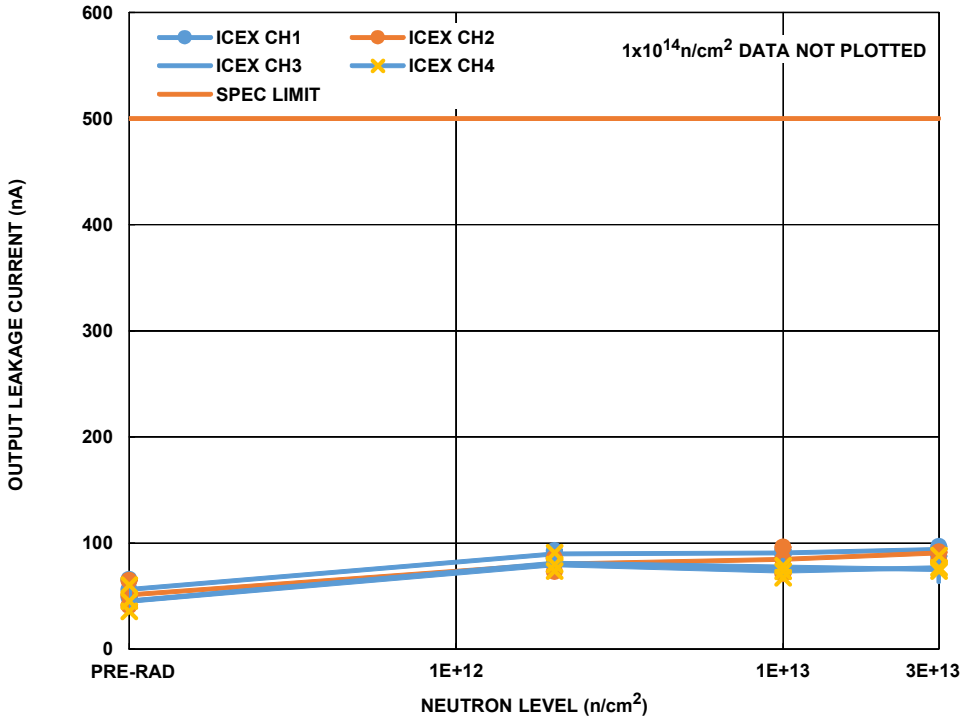

Figure 15. IS-139ASRH Output Leakage (ICEX), each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limit is 500nA maximum.

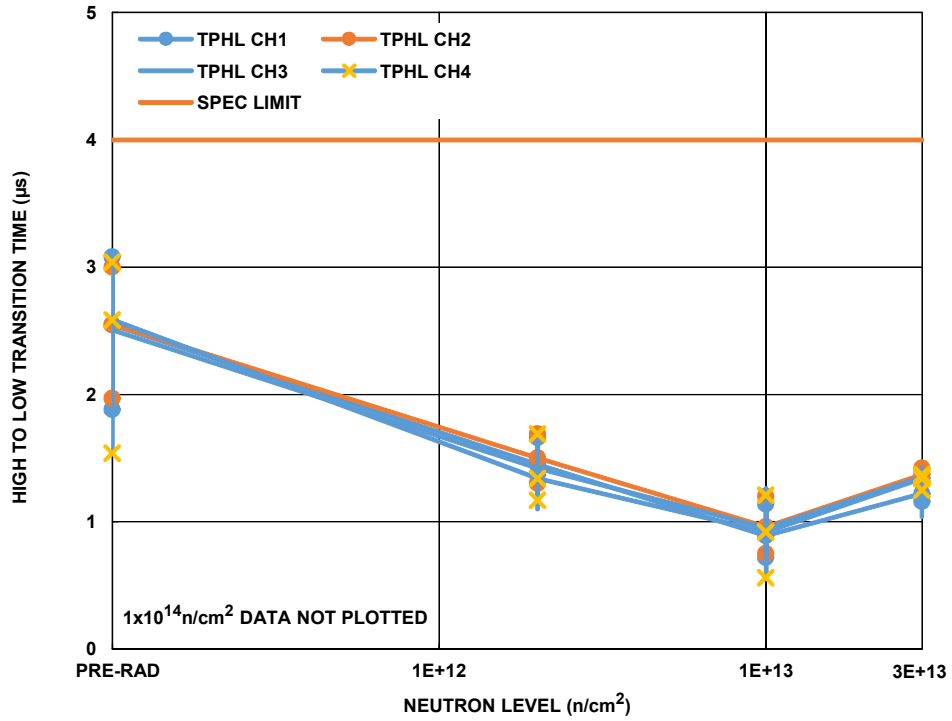

Figure 16. IS-139ASRH HIGH to LOW response time, V_{OD} = V_{IO} + 5mV, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limit is 4µs maximum.

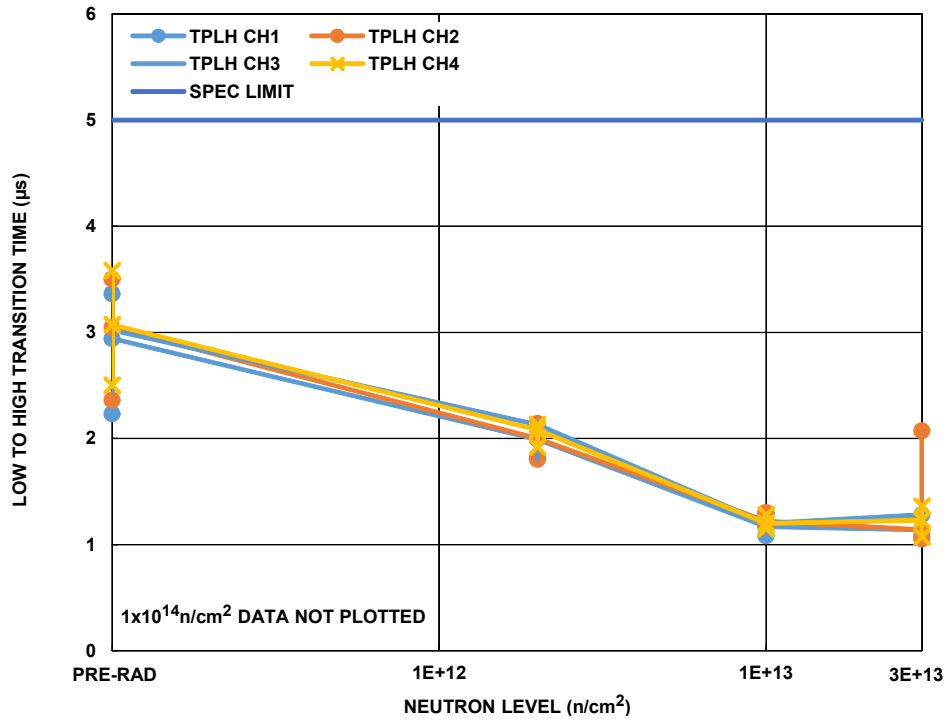

Figure 17. IS-139ASRH LOW to HIGH response time, V_{OD} = V_{IO} + 5mV, each of four channels, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$ and $3x10^{13}n/cm^2$. All samples were nonfunctional after $1x10^{14}n/cm^2$ and that data is not plotted. The plot shows the population median, minimum and maximum at each downpoint. Sample size for each cell was 5. The post-total dose irradiation SMD limit is 5µs maximum.

3. Conclusion

This report summarizes results of 1MeV equivalent neutron testing of the IS-139ASRH quad comparator. The test was conducted in order to determine the sensitivity of the part to displacement damage (DD) caused by neutron or proton environments in space. Neutron fluences ranged from $2x10^{12}n/cm^2$ to $1x10^{14}n/cm^2$. This project was carried out in collaboration with Boeing (El Segundo, CA), whose support is gratefully acknowledged.

The samples met all specifications (Bin 1) after $2x10^{12}n/cm^2$. Four failed parametrically (input bias current and input offset current) after $1x10^{13}n/cm^2$, while five failed parametrically (again input bias current and input offset current) after $3x10^{13}n/cm^2$. All samples were nonfunctional after the $1x10^{14}n/cm^2$ irradiation testing, and we omitted plotting the resulting extreme ATE overrange values as they are meaningless; rather, they make the data at the other three levels much more difficult to interpret by distorting the vertical axis scale.

4. Appendices

4.1 Reported Parameters

Reported parameters are shown in Table 3. The limits are taken from the applicable SMD. A number of parameters are plotted in the same figure (see, for example, Figure 2, which plots the neutron response of both the enable LOW and enable HIGH currents) in order to save space. The plots show the population median and minimum and maximum bars at each downpoint.

Table 3. Reported Parameters

Figure	Parameter	Low Limi	High Limit	Unit	Notes
1	Power supply current	-	3.5	mA	9V supply
	Power supply current	-	3.5	mA	30V supply
2	Input offset voltage	-9	9	mV	9V supply
3	Input offset voltage	-9	9	mV	30V supply
4	Negative input bias current	-1000	1000	nA	9V supply
5	Negative input bias current	-1000	1000	nA	30V supply
6	Positive input bias current	-1000	1000	nA	9V supply
7	Positive input bias current	-1000	1000	nA	30V supply
8	Input offset current	-500	500	nA	9V supply
9	Input offset current	-500	500	nA	30V supply
10	Open loop gain	25	-	V/mV	
11	Common mode rejection ratio	70	-	dB	
12	Power supply rejection ratio	60	-	dB	Not in SMD, ATE limit
13	Output saturation voltage	-	300	mV	
14	Output sink current	12	-	mA	
15	Output leakage	-	500	nA	
16	HIGH to LOW response time	-	4	µs	
17	LOW to HIGH response time	-	5	µs	

5. Revision History

Revision	Date	Description
1.00	Apr 25, 2025	Applied new template. Updated Variables Data section. Updated Reported Parameters section.
0.00	Nov 14, 2016	Initial release.

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