ISL73141SEH

Neutron Testing of the ISL73141SEHMFN 3.3V, 14-Bit, 750ksps SAR ADC

Introduction

This report summarizes results of 1MeV equivalent neutron testing of the ISL73141SEHMFN, the 3.3V version of the ISL73141SEH 14-Bit, 750ksps Successive Approximation Register (SAR) Analog-to-Digital Converter (ADC), but the results apply to the 5V version (ISL73141SEHMF7) as well. The test was conducted to determine the sensitivity of the part to displacement damage (DD) caused by neutron or proton environments. Neutron fluences ranged from 5×10^{11}n/cm^2 to 1×10^{13}n/cm^2.

Product Description

The ISL73141SEH is a radiation hardened high precision 14-bit, SAR ADC that features a Signal-to-Noise Ratio (SNR) of 80.3dBFS with 3.3V supply while operating at 750ksps with a power consumption of 28mW.

The ISL73141SEH features 750ksps throughput at 3.3V with no data latency and features excellent linearity and dynamic accuracy. It also provides a high-speed SPI-compatible serial interface that supports logic ranging from 2.2V to 3.6V using a separate digital I/O supply pin.

The ISL73141SEH provides a separate power-down pin that reduces power dissipation to <50µW. The analog input signal range is determined by an external reference.

The ISL73141SEH operates across the military temperature range from -55°C to +125°C and is available in a 14-lead hermetically sealed Ceramic Dual Flat-Pack (CDFP) package.

A typical application schematic for the ISL73141SEH is shown in Figure 1.

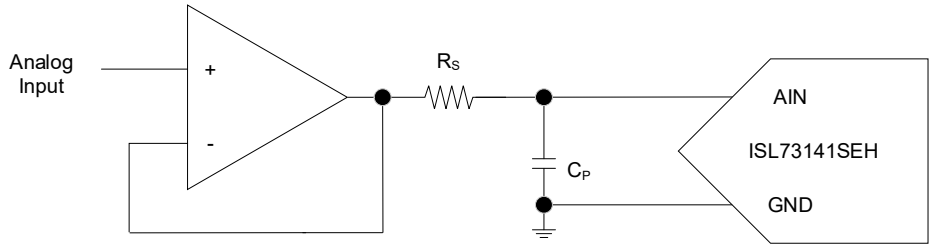

Figure 1. Typical Application Schematic

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Contents

1. Test Description

1.1 Irradiation Facility

Neutron fluence irradiations were performed on the test samples on August 1, 2022, at the University of Massachusetts, Lowell (UMASS Lowell) fast neutron irradiator per Mil-STD-883G, Method 1017.2, with each part unpowered during irradiation. The target irradiation levels were 5×10^{11}n/cm^2, 2×10^{12}n/cm^2, and 1×10^{13}n/cm^2. 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 Renesas (Palm Bay, FL) for electrical testing.

1.2 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 unbiased.

1.3 Radiation Dosimetry

Table 1 shows dosimetry from UMASS Lowell indicating the total accumulated gamma dose and actual neutron fluence exposure levels for each set of samples.

Table 1. Neutron Fluence Dosimetry Data

Irradiation	Requested Fluence (n/cm^2)	Reactor Power (kW)	Time (s)	Fluence Rate (n/cm^2-s)[1][2]	Gamma Dose (rad(Si))[3]	Measured Fluence (n/cm^2)[4]
CRF#62106-A	5.00E+11	10	617	8.10E+08	70	5.38E+11
CRF#62106-B	2.00E+12	100	247	8.10E+09	281	2.05E+12
CRF#62106-C	1.00E+13	1000	123	8.10E+10	1401	1.14E+13

1. Dosimetry method: ASTM E-265.
2. The neutron fluence rate is determined from *Initial Testing of the New Ex-Core Fast Neutron Irradiator at UMass Lowell (6/18/02)*. Validated on 6/07/2011 under the Trident II D5LE neutron facility study by Navy Crane.
3. Based on reactor power at 1000kW, the gamma dose is 41krad(Si)/hr ±5.3% as mapped by TLD-based dosimetry.
4. Validated by S-32 flux monitors.

1.4 Characterization Equipment and Procedures

Electrical testing was performed before and after irradiation using the Renesas production automated test equipment (ATE). All electrical testing was performed at room temperature.

1.5 Experimental Matrix

Testing proceeded in general accordance with the guidelines of MIL-STD-883 TM 1017. The experimental matrix consisted of five samples to be irradiated at 5×10^{11}n/cm^2, five to be irradiated at 2×10^{12}n/cm^2, and five to be irradiated at 1×10^{13}n/cm^2. The actual levels achieved, which are shown in Table 2, were 5.38×10^{11}n/cm^2, 2.05×10^{12}n/cm^2, and 1.14×10^{13}n/cm^2. Three control units were used.

The 15 ISL73141SEH samples were drawn from Lot V6C4983B. Samples were packaged in the 14-lead hermetically sealed Ceramic Dual Flat-Pack (CDFP) production package. Samples were processed through burn-in before irradiation and were screened to the datasheet limits at room, low, and high temperatures before the start of neutron testing.

2. Results

Neutron testing of the ISL73141SEH is complete, and the results are reported in the balance of this report. It should be understood when interpreting the data that each neutron irradiation was performed on a different set of samples; this is not total dose testing, where the damage is cumulative.

2.1 Attributes Data

Table 2. Attributes Data

1MeV Fluence, (n/cm^2)		Sample Size	Pass[1]	Fail	Notes
Planned	Actual				
5×10^{11}	5.38×10^{11}	5	5	0	All passed
2×10^{12}	2.05×10^{12}	5	5	0	All passed
1×10^{13}	1.14×10^{13}	5	5	0	All passed

1. A pass indicates a sample that passes all datasheet limits.

2.2 Variables Data

The plots in Figure 2 through Figure 30 show data plots for key parameters before and after irradiation to each level. The plots show the mean of each parameter as a function of neutron irradiation. The plots also include error bars at each down-point, representing the minimum and maximum measured values of the samples, although in some plots the error bars might not be visible because of their values compared to the scale of the graph. While the applicable electrical limits taken from the datasheet are also shown, it should be noted that these limits are provided for guidance only as the ISL73141SEH is not specified for the neutron environment.

All samples passed the post - TID irradiation datasheet limits after all three exposures up to and including $1.14\times10^{13}n/cm^2$.

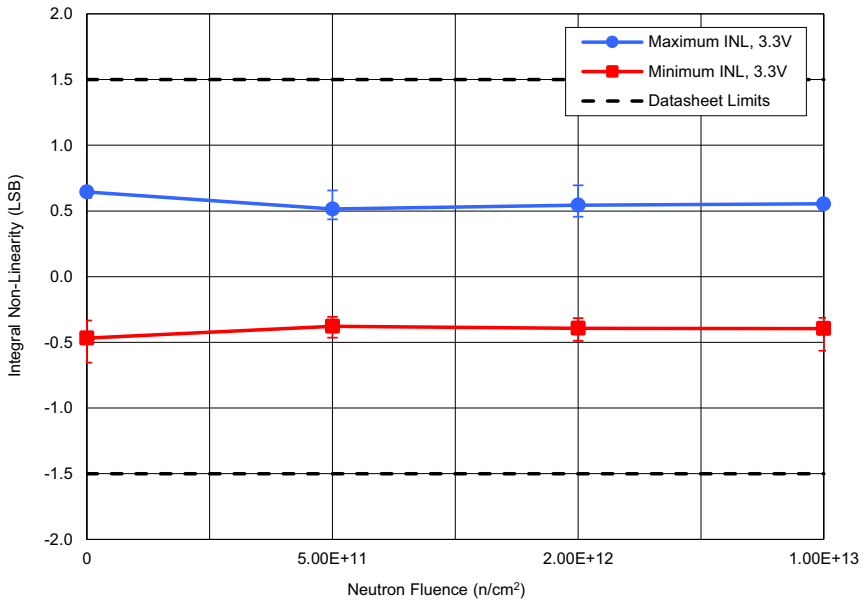

Figure 2. ISL73141SEH average minimum and maximum integral non-linearity (INL) with AV_{CC} = 3.3V, DV = 2.5V, REF = 3.0V, f_{SAMP} = 750ksps, and A_{IN} = full-scale sine wave following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are a minimum of -1.5LSB with a maximum of 1.5LSB.

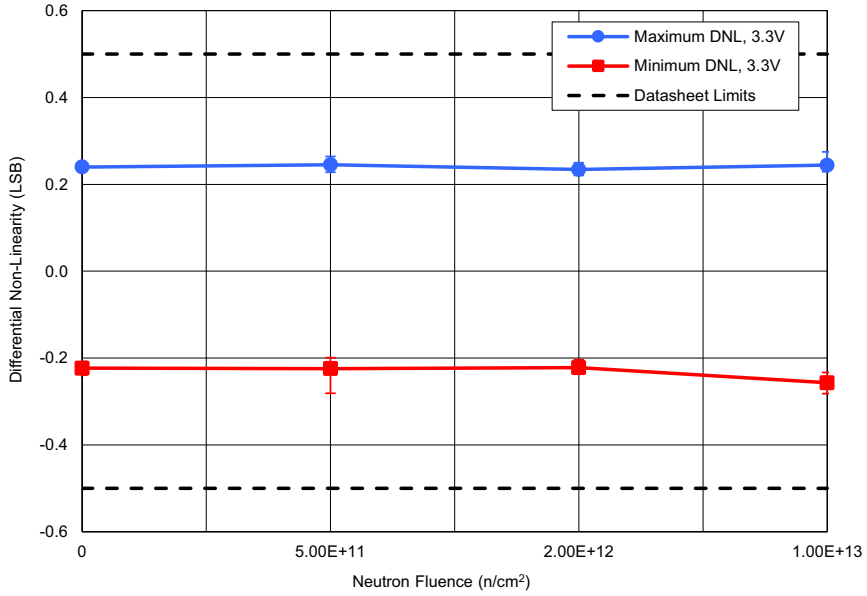

Figure 3. ISL73141SEH average minimum and maximum differential non-linearity (DNL) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, f_{SAMP} = 750ksps, and A_{IN} = full-scale sine wave following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are a minimum of -0.5LSB with a maximum of 0.5LSB.

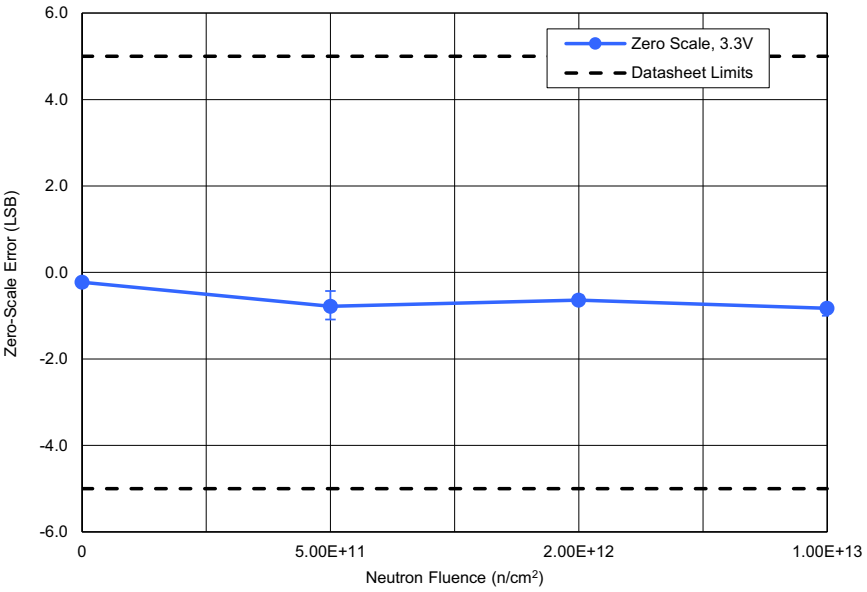

Figure 4. ISL73141SEH average zero scale error (VOFF) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, f_{SAMP} = 750ksps, and A_{IN} = GND following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are a minimum of -5LSB with a maximum of 5LSB.

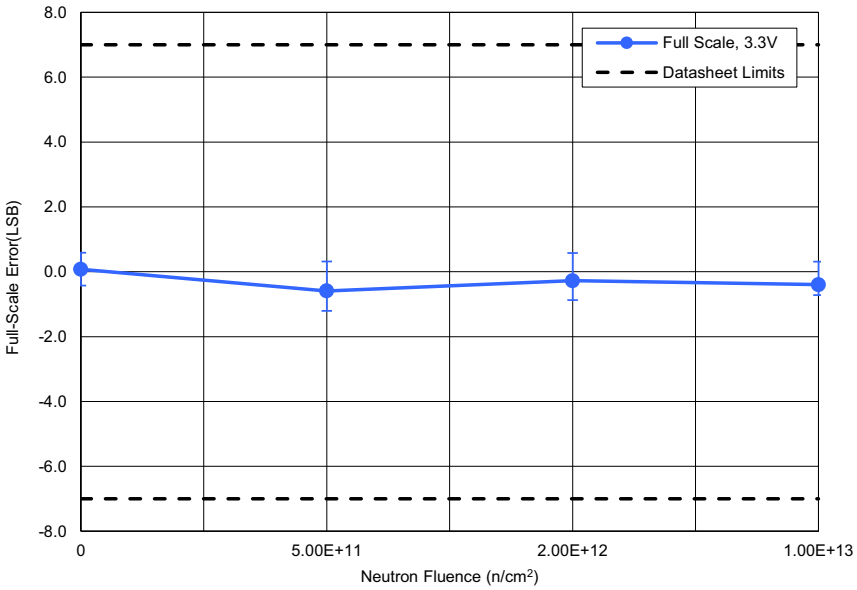

Figure 5. ISL73141SEH average full-scale error (FSE) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, f_{SAMP} = 750ksps, and A_{IN} = VREF following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are a minimum of -7LSB with a maximum of 7LSB.

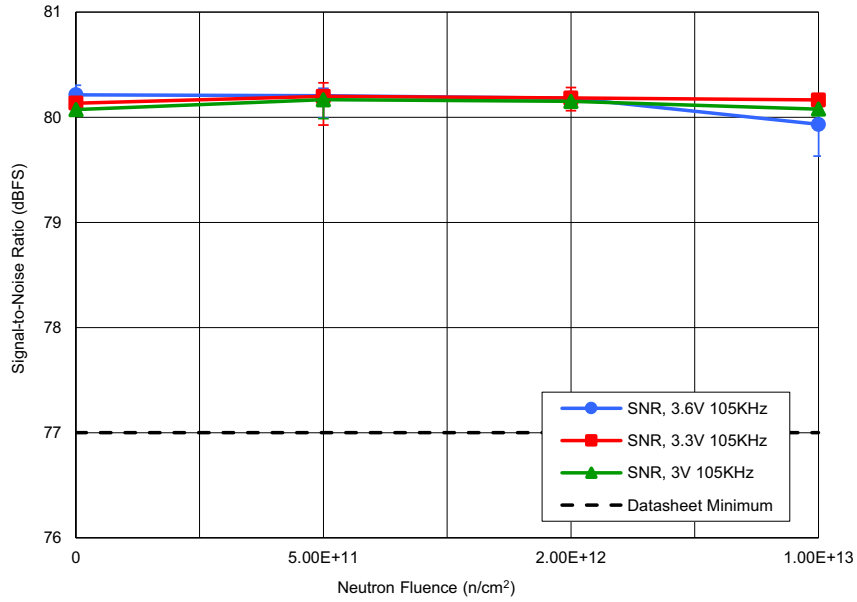

Figure 6. ISL73141SEH average signal-to-noise ratio (SNR) with AV_{CC} = 3.6V, 3.3V and 3.0V, DV_{CC} = 2.5V, REF = 3.0V, F_{IN} = 105kHz, and A_{IN} = -1dBFS following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a minimum of 77dB.

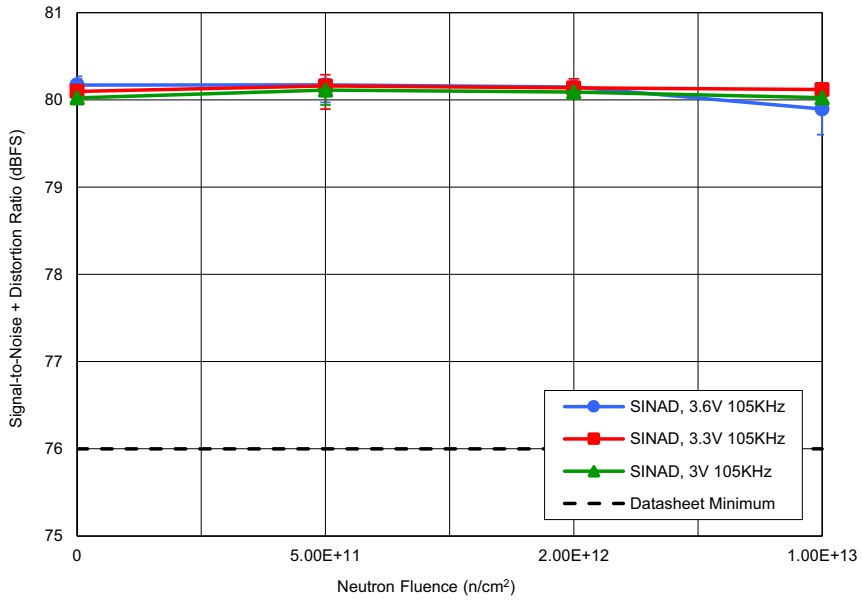

Figure 7. ISL73141SEH average signal-to-noise + distortion ratio (SINAD) with AV_{CC} = 3.6V, 3.3V and 3.0V, DV_{CC} = 2.5V, REF = 3.0V, F_{IN} = 105kHz, and A_{IN} = -1dBFS following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a minimum of 76dB.

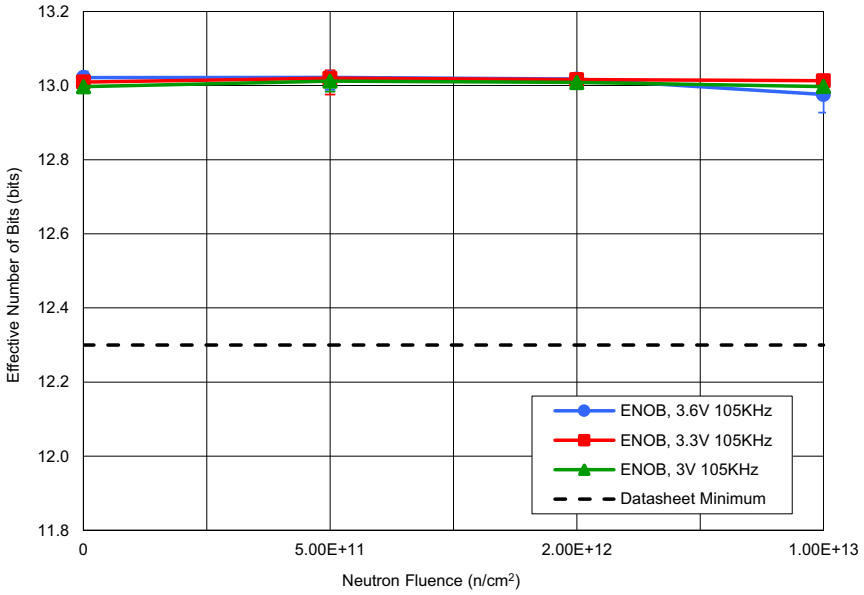

Figure 8. ISL73141SEH average effective number of bits (ENOB) with AV_{CC} = 3.6V, 3.3V and 3.0V, DV_{CC} = 2.5V, REF = 3.0V, F_{IN} = 105kHz, and A_{IN} = -1dBFS following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a minimum of 12.3bits.

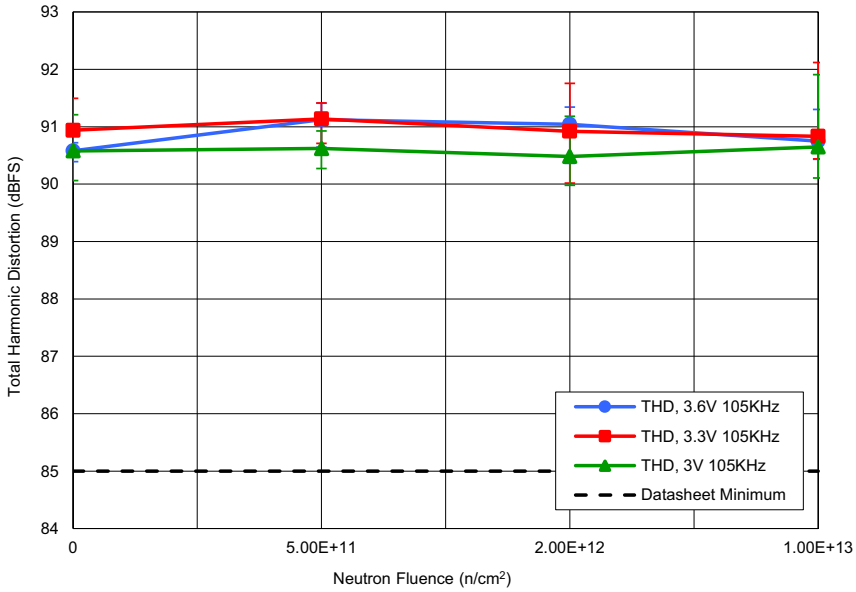

Figure 9. ISL73141SEH average total harmonic distortion (THD) with AV_{CC} = 3.6V, 3.3V and 3.0V, DV_{CC} = 2.5V, REF = 3.0V, F_{IN} = 105kHz (first five harmonics), and A_{IN} = -1dBFS following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a minimum of 85dB.

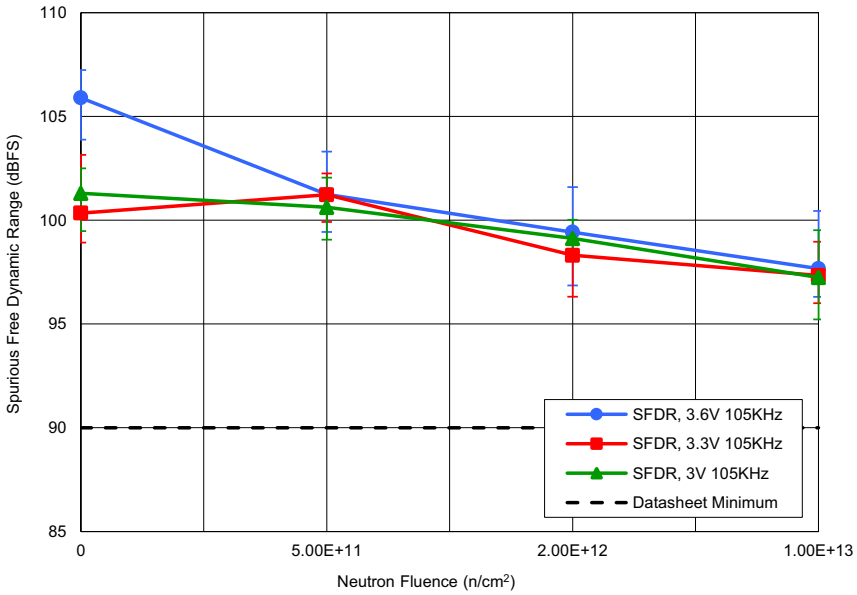

Figure 10. ISL73141SEH average spurious free dynamic range (SFDR) with AV_{CC} = 3.6V, 3.3V and 3.0V, DV_{CC} = 2.5V, REF = 3.0V, F_{IN} = 105kHz (first five harmonics excluded), and A_{IN} = -1dBFS following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a minimum of 90dB.

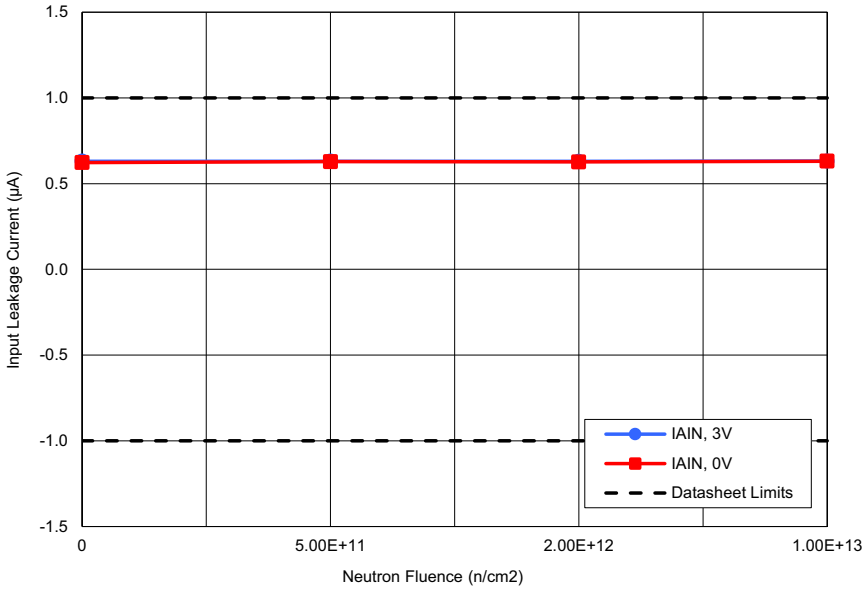

Figure 11. ISL73141SEH average input leakage current (I_{AIN}) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, f_{SAMP} = 750ksps, and A_{IN} = 3.0V and 0V following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are a minimum of -1µA with a maximum of 1µA.

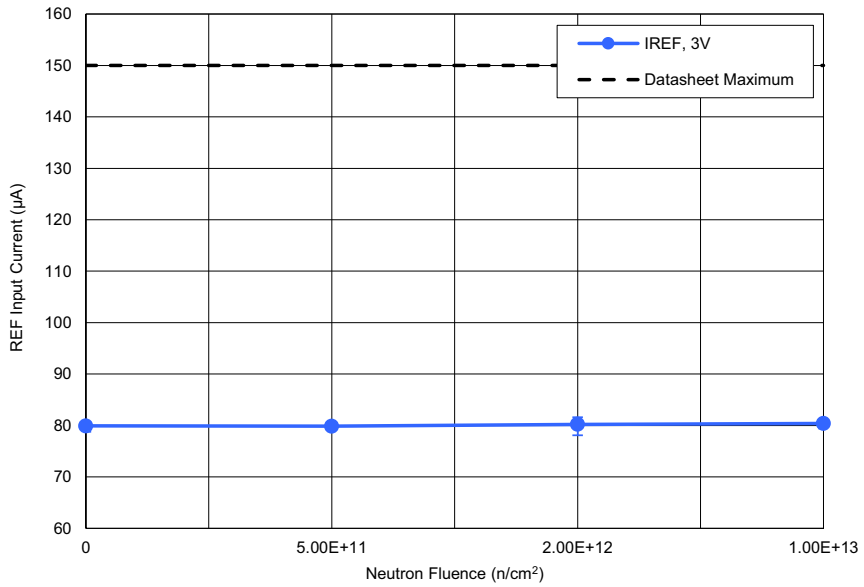

Figure 12. ISL73141SEH average REF input current (I_{REF}) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, f_{SAMP} = 750ksps, and A_{IN} = -1dBFS following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 150µA.

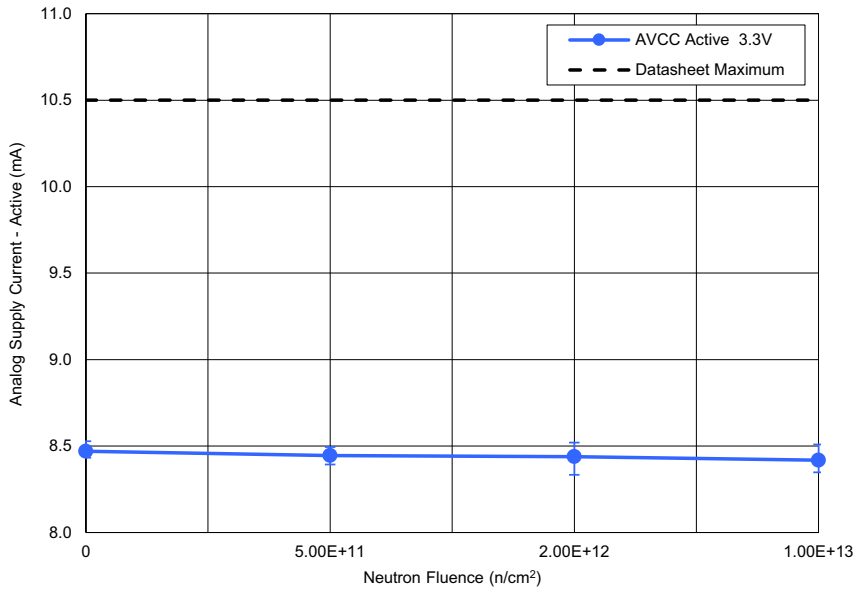

Figure 13. ISL73141SEH average analog supply current – active (I_{AVCC}) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, f_{SAMP} = 750ksps, and A_{IN} = -1dBFS following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 10.5mA.

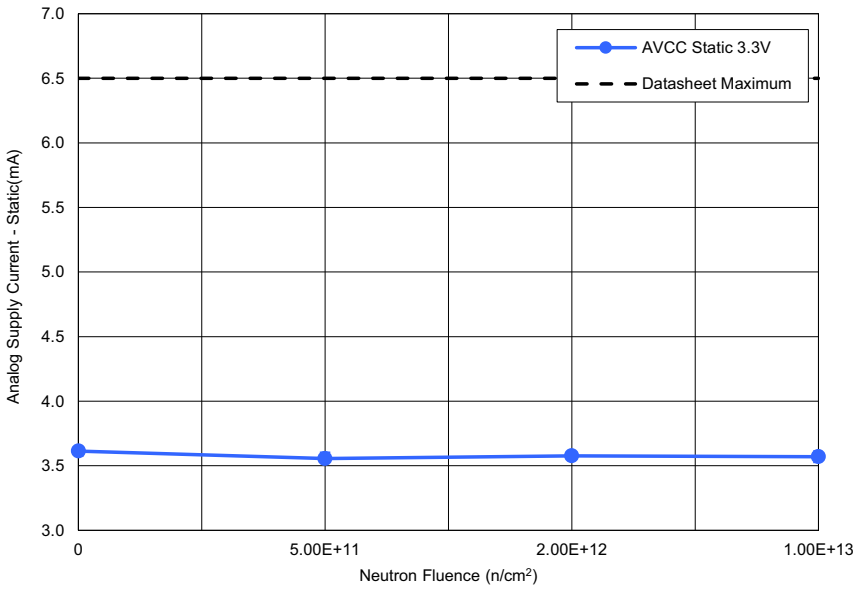

Figure 14. ISL73141SEH average analog supply current – static (I_{STATIC}) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, and $\overline{CS}$ = DV_{CC} following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 6.5mA.

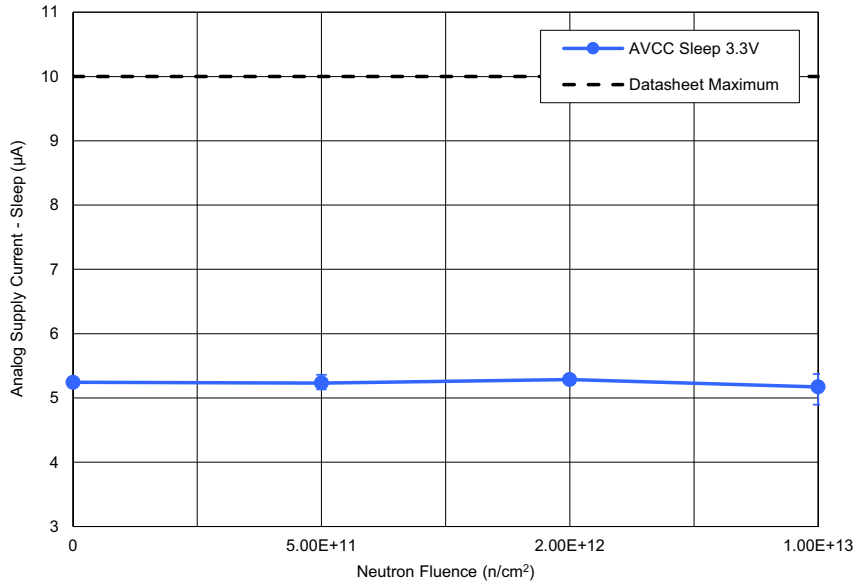

Figure 15. ISL73141SEH average analog supply current – sleep (I_{SLAVCC}) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, and $\overline{PD}$ = GND following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 10µA.

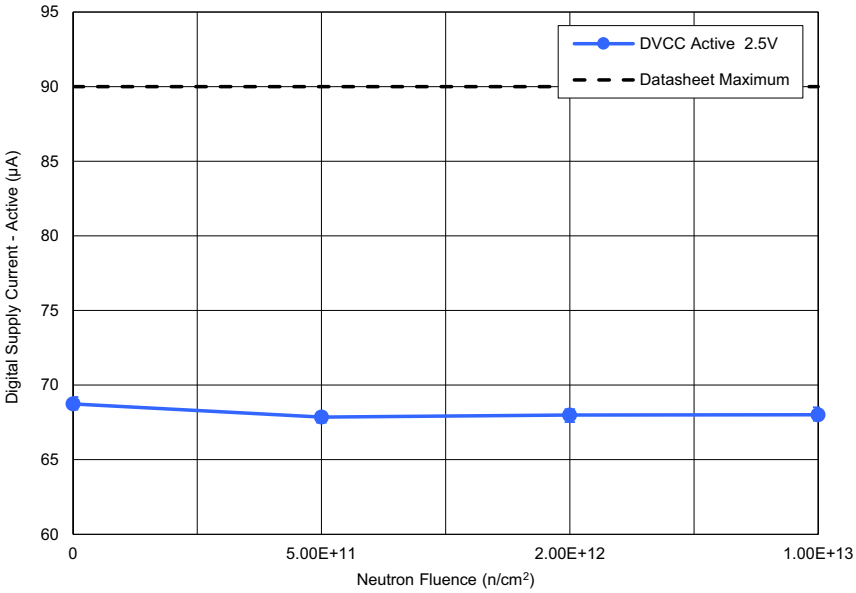

Figure 16. ISL73141SEH average digital supply current – active (I_{DVCC}) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, f_{SCK} = 33MHz, and C_L = 10pF following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 90µA.

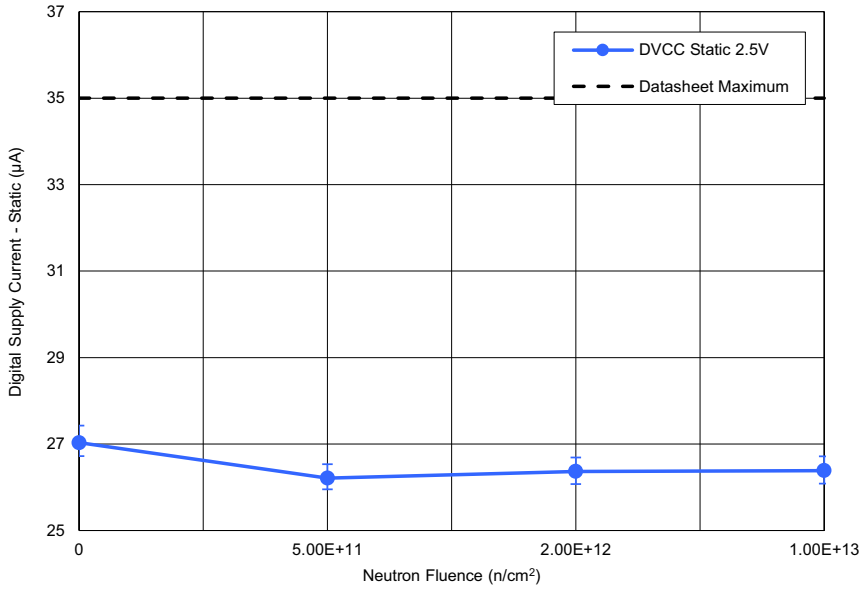

Figure 17. ISL73141SEH average digital supply current – static (I_{STDVCC}) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, and $\overline{CS}$ = DV_{CC} following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 35µA.

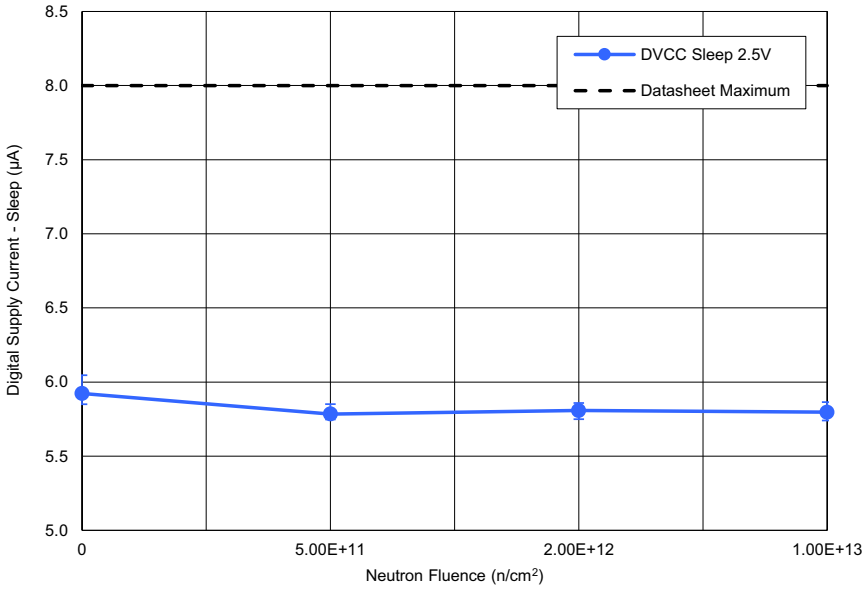

Figure 18. ISL73141SEH average digital supply current – sleep (I_{SLDVCC}) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, and $\overline{PD}$ = GND following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 8µA.

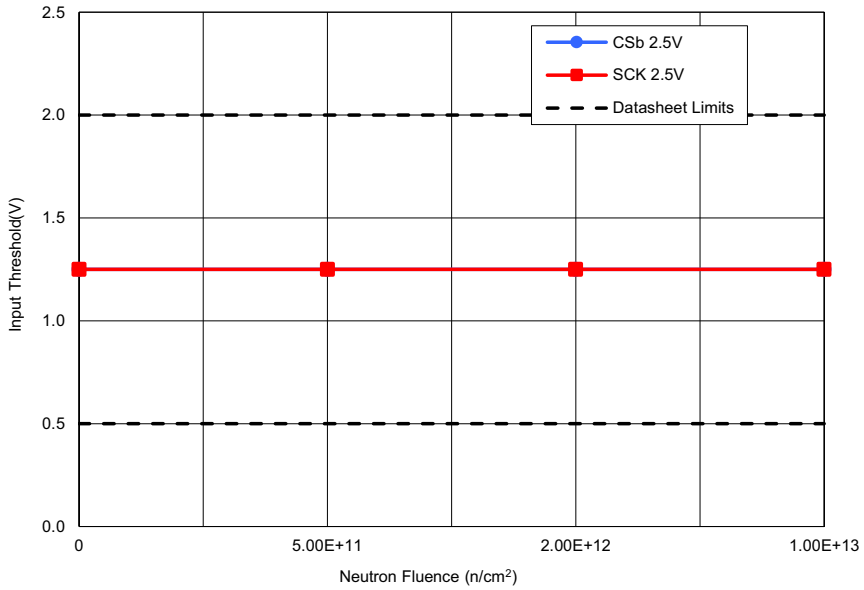

Figure 19. ISL73141SEH average high-level input (V_{IH}) and low-level input (V_{IL}) with AV_{CC} = 3.3V, DV_{CC} = 2.5V, and REF = 3.0V following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are a 2.0V minimum for V_{IH} and a 0.5V maximum for V_{IL}.

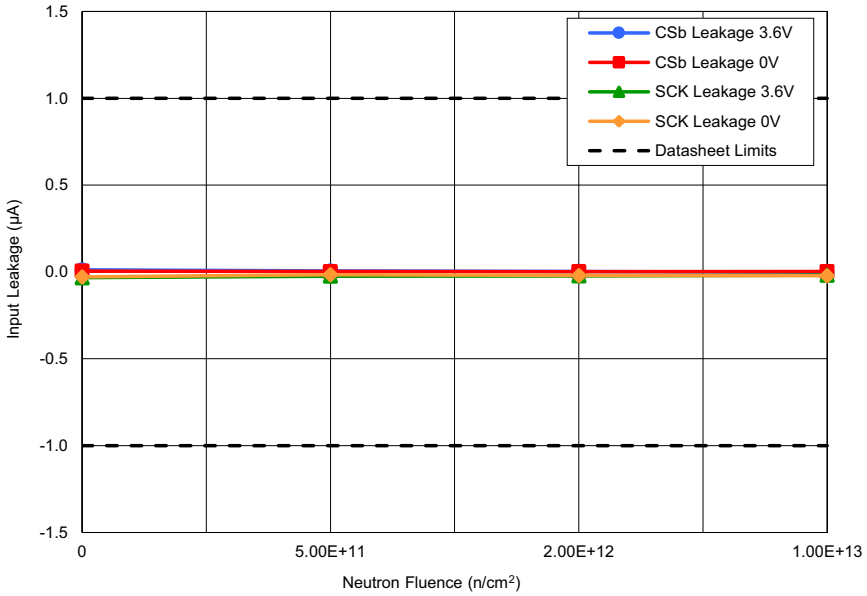

Figure 20. ISL73141SEH average input leakage current (I_{IN}) on SCK and $\overline{CS}$ with AV_{CC} = 3.3V, DV_{CC} = 2.5V, REF = 3.0V, and V_{IN} = 3.6V and 0V following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are a minimum of -1µA with a maximum of 1µA.

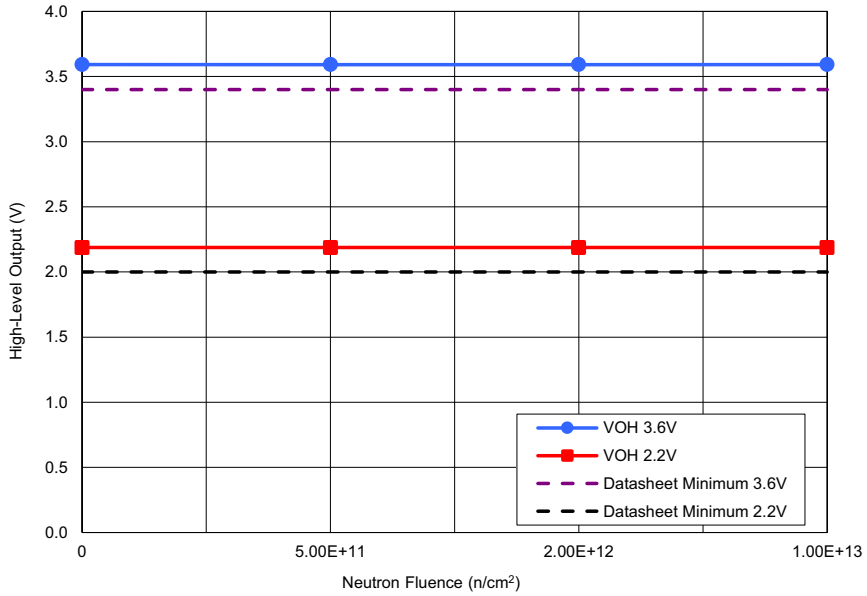

Figure 21. ISL73141SEH average high-level output (V_{OH}) with AV_{CC} = 3.3V, DV_{CC} = 3.6V and 2.2V, REF = 3.0V, and I_O = -500µA following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are minimums of 3.4V for DV_{CC} = 3.6V and 2.0V for DV_{CC} = 2.2V.

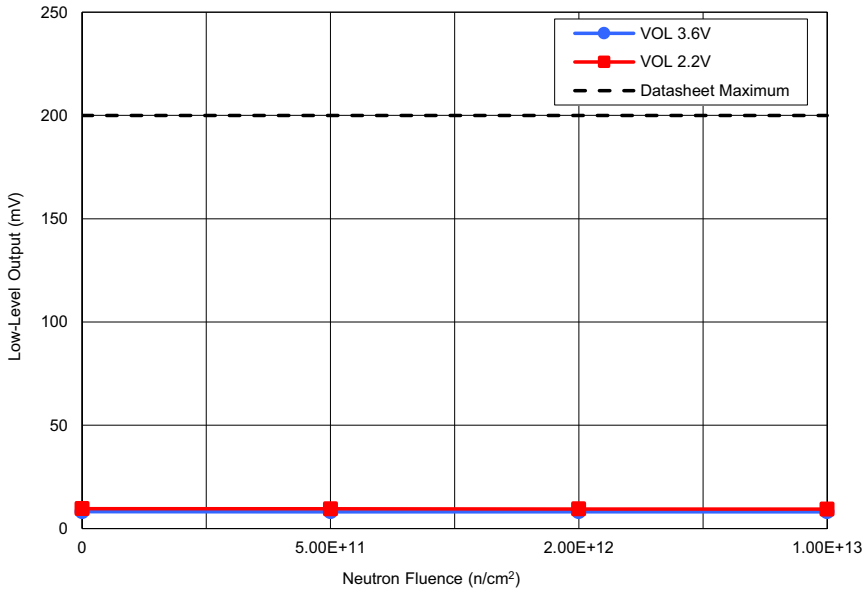

Figure 22. ISL73141SEH average low-level output (V_{OL}) with AV_{CC} = 3.3V, DV_{CC} = 3.6V and 2.2V, REF = 3.0V, and I_O = 500µA following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 200mV.

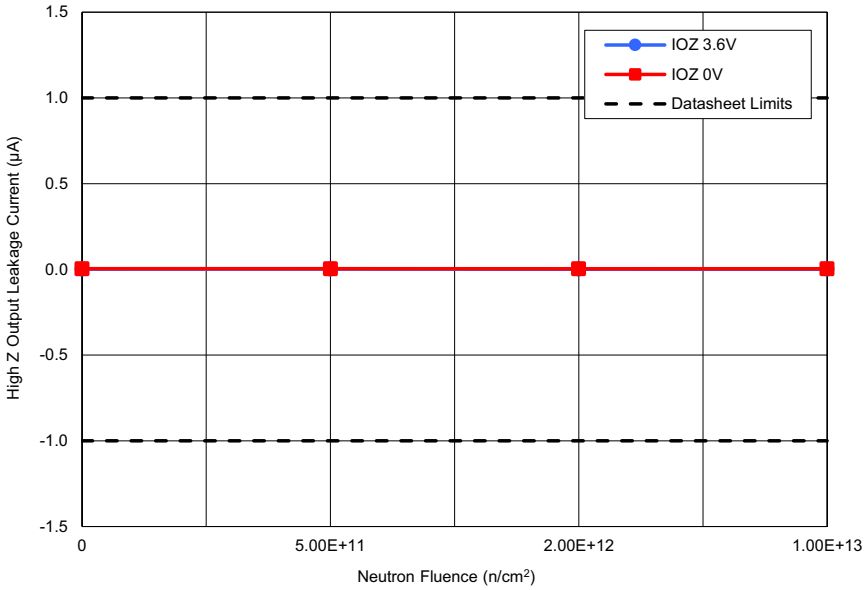

Figure 23. ISL73141SEH average Hi-Z output leakage current (I_{OZ}) with AV_{CC} = 3.3V, DV_{CC} = 3.6V, V_{OUT} = 3.6V and 0V, and REF = 3.0V following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are a minimum of -1µA with a maximum of 1µA.

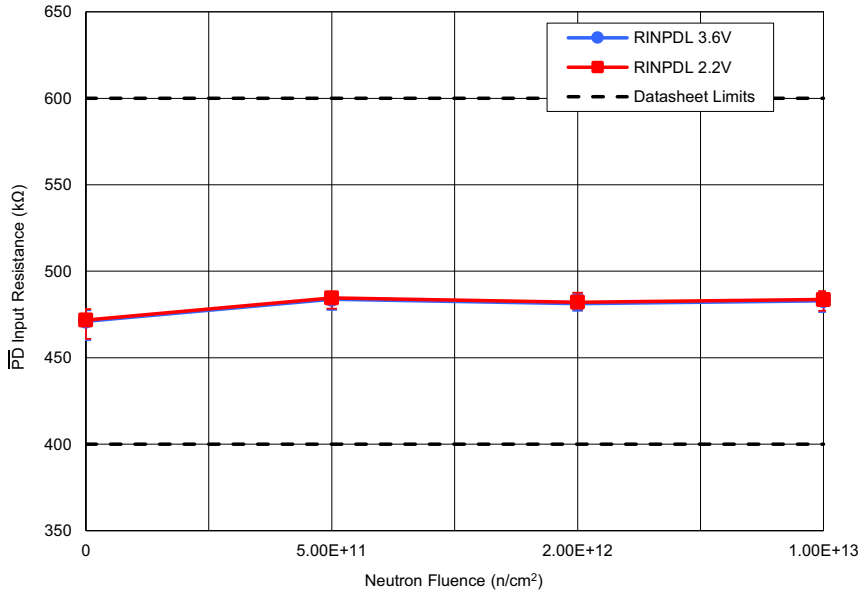

Figure 24. ISL73141SEH average $\overline{PD}$ input resistance (R_{INPDL}) with AV_{CC} = 3.3V, DV_{CC} = 3.6V and 2.2V, and REF = 3.0V following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limits are a minimum of 400kΩ with a maximum of 600kΩ.

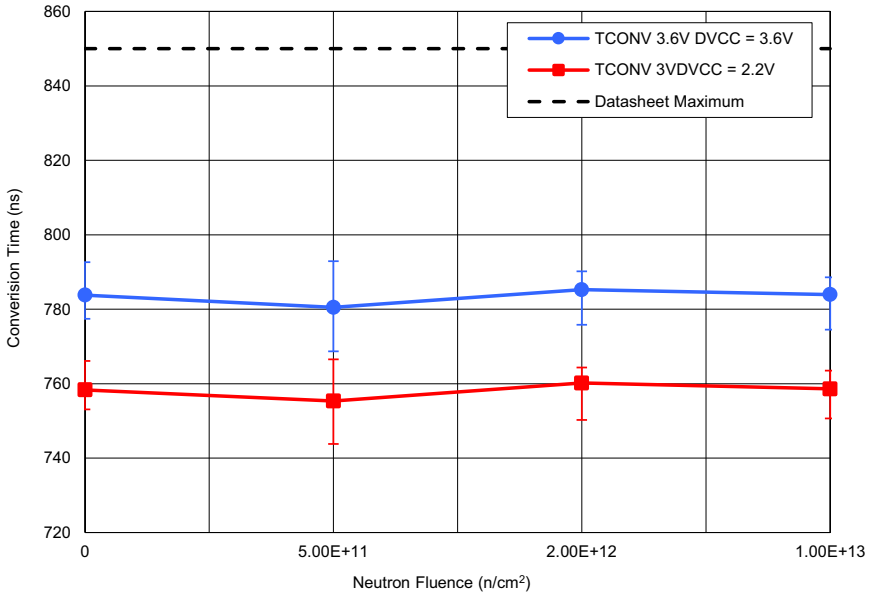

Figure 25. ISL73141SEH average conversion time (t_{CONV}) with AV_{CC} = 3.6V, DV_{CC} = 3.6V and AV_{CC} = 3.0V, DV_{CC} = 2.2V, REF = 3.0V, f_{SAMP} = 750ksps, and A_{IN} = -1dBFS following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 850ns.

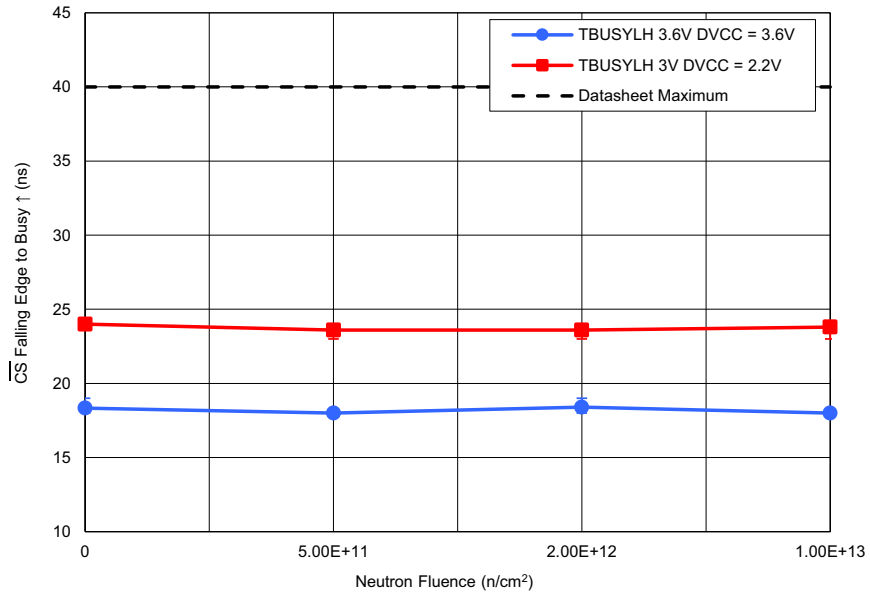

Figure 26. ISL73141SEH average $\overline{CS}$ falling edge to BUSY rising edge (t_{BUSYLH}) with AV_{CC} = 3.6V, DV_{CC} = 3.6V and AV_{CC} = 3.0V, DV_{CC} = 2.2V, REF = 3.0V, f_{SAMP} = 750ksps, A_{IN} = -1dBFS, and C_L = 10pF following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 40ns.

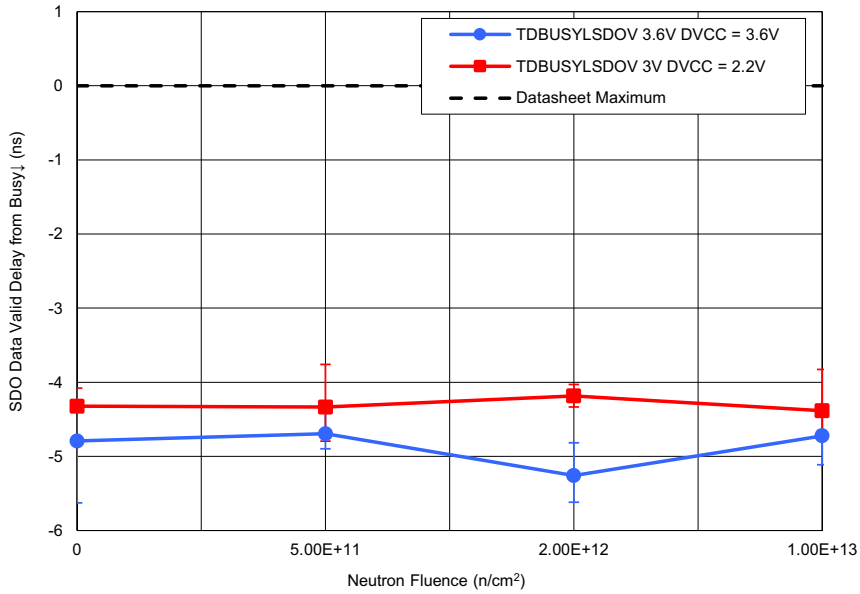

Figure 27. ISL73141SEH average SDO data valid delay from BUSY falling edge ($t_{DBUSYLSDOV}$) with AV_{CC} = 3.6V, DV_{CC} = 3.6V and AV_{CC} = 3.0V, DV_{CC} = 2.2V, REF = 3.0V, f_{SAMP} = 750ksps, A_{IN} = -1dBFS, and C_L = 10pF following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 0ns.

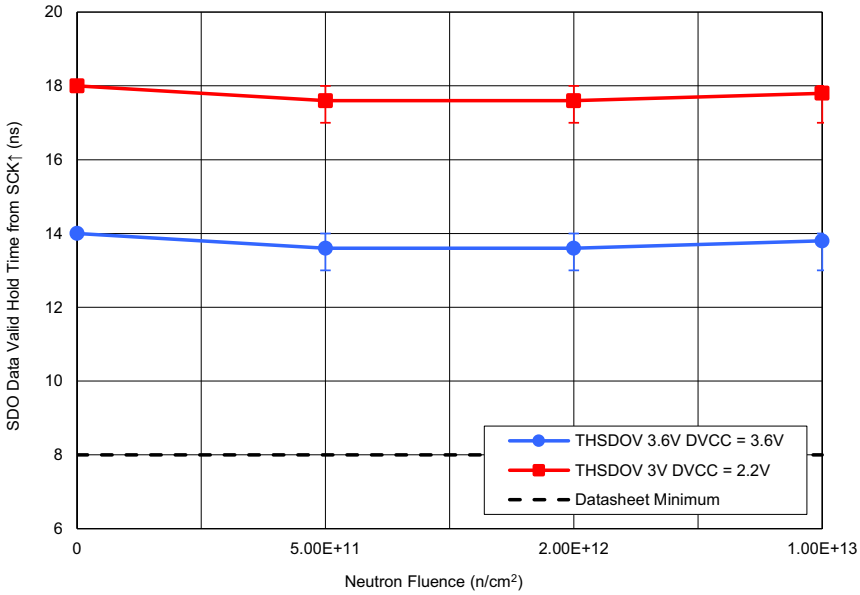

Figure 28. ISL73141SEH average SDO data valid hold time from SCK rising edge (t_{HSDOV}) with AV_{CC} = 3.6V, DV_{CC} = 3.6V and AV_{CC} = 3.0V, DV_{CC} = 2.2V, REF = 3.0V, f_{SAMP} = 750ksps, A_{IN} = -1dBFS, and C_L = 10pF following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a minimum of 8ns.

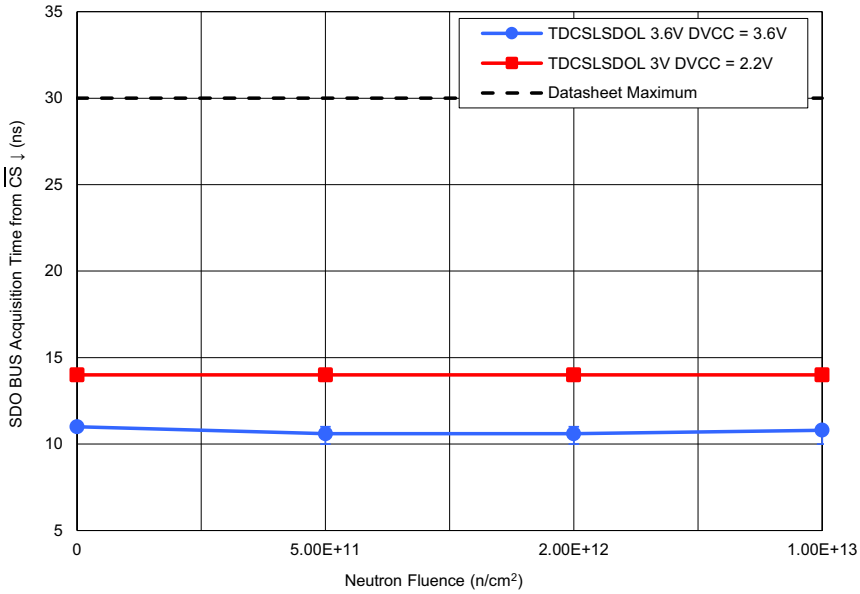

Figure 29. ISL73141SEH average SDO bus acquisition time from $\overline{CS}$ falling edge ($t_{DCSLSDOL}$) with AV_{CC} = 3.6V, DV_{CC} = 3.6V and AV_{CC} = 3.0V, DV_{CC} = 2.2V, REF = 3.0V, f_{SAMP} = 750ksps, A_{IN} = -1dBFS, and C_L = 10pF following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 30ns.

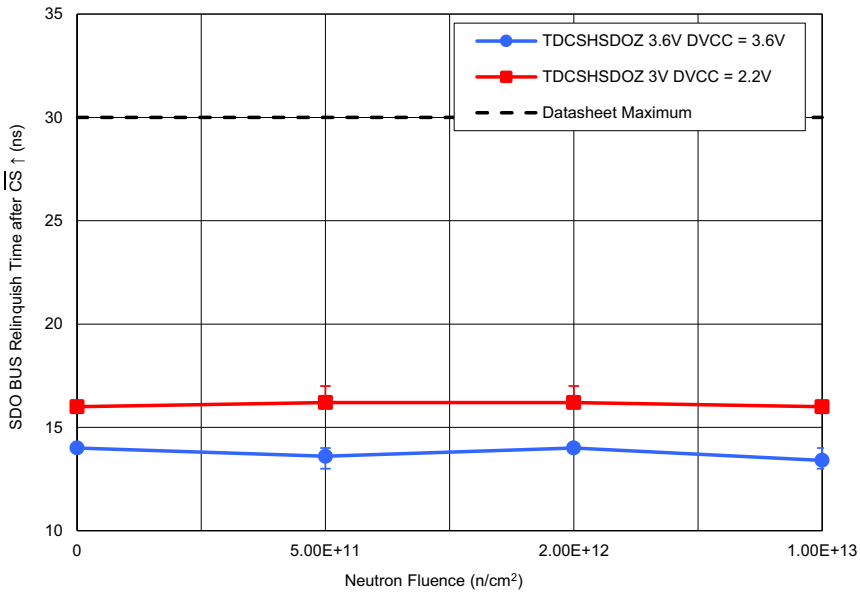

Figure 30. ISL73141SEH average SDO bus relinquish time after $\overline{CS}$ raising edge ($t_{DCSHSDOZ}$) with AV_{CC} = 3.6V, DV_{CC} = 3.6V and AV_{CC} = 3.0V, DV_{CC} = 2.2V, REF = 3.0V, f_{SAMP} = 750ksps, A_{IN} = -1dBFS, and C_L = 10pF following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post – TID irradiation datasheet limit is a maximum of 30ns.

3. Discussion and Conclusion

This document reports the results of 1MeV equivalent neutron testing of the ISL73141SEH 3.3V, 14-Bit, 750ksps SAR ADC. Parts were tested at actual fluences of 5.38×10^{11}n/cm^2, 2.05×10^{12}n/cm^2 and 1.14×10^{13}n/cm^2. The results of key parameters before and after irradiation to each level are plotted in Figure 2 through Figure 30. The plots show the mean of each parameter as a function of neutron irradiation, with error bars that represent the minimum and maximum measured values. The figures also show the applicable electrical limits taken from the datasheet, but it should be noted that these limits are provided for guidance only as the ISL73141SEH is not specified for the neutron environment.

All samples passed the post - TID irradiation datasheet limits after all three exposures up to and including 1.14×10^{13}n/cm^2.

4. Revision History

Revision	Date	Description
1.00	Sep 6, 2022	Initial release.

Appendix

Table 3. Reported Parameters

Figure	Parameter	Symbol	Conditions	Low Limit	High Limit	Unit
2	Integral Non-Linearity	INL	Measured with full-scale input signal	-1.5	1.5	LSB
3	Differential Non-Linearity	DNL	Measured with full-scale input signal	-0.5	0.5	LSB
4	Zero-Scale Error	VOFF	Measured with input grounded	-5	5	LSB
5	Full-Scale Error	FSE	Measured with input connected to VREF	-7	7	LSB
6	Signal to Noise Ratio	SNR	F_{IN} = 105kHz	77	-	dB
7	Signal to Noise + Distortion Ratio	SINAD	F_{IN} = 105kHz	76	-	dB
8	Effective Number of Bits	ENOB	F_{IN} = 105kHz	12.3	-	bits
9	Total Harmonic Distortion	THD	F_{IN} = 105kHz, first five harmonics	85	-	dB
10	Spurious Free Dynamic Range	SFDR	F_{IN} = 105kHz, first five harmonics excluded	90	-	dB
11	Input Leakage Current	I_{AIN}		-1	1	µA
12	REF Input Current	I_{REF}		-	150	µA
13	Analog Supply Current – Active	I_{AVCC}	Active, f_{SAMP} = 750ksps	-	10.5	mA
14	Analog Supply Current – Static	I_{STATIC}	$\overline{CS}$ held high	-	6.5	mA
15	Analog Supply Current - Sleep	I_{SLAVCC}	$\overline{PD}$ held low	-	10	µA
16	Digital Supply Current – Active	I_{DVCC}	f_{SCK} = 33MHz, 10pF load	-	90	µA
17	Digital Supply Current – Static	I_{STDVCC}	$\overline{CS}$ held high	-	35	µA
18	Digital Supply Current – Sleep	I_{SLDVCC}	$\overline{PD}$ held low	-	8	µA
19	High Input Level	V_{IH}		0.8×DV_{CC}	-	V
	Low Input Level	V_{IL}		-	0.2×DV_{CC}	V
20	Input Current ($\overline{CS}$, SCK)	I_{IN}	V_{IN} = 0V to DV_{CC}	-1	1	µA
21	High Level Output	V_{OH}	DV_{CC} - Output, I_O = -500µA	DV_{CC} – 0.2V	-	V
22	Low Level Output	V_{OL}	I_O = 500µA	-	200	mV
23	Hi-Z Output Leakage Current	I_{OZ}	V_{OUT} = 0V to DV_{CC}	-1	1	µA
24	$\overline{PD}$ Input Resistance	R_{INPDL}	Internal pull-up resistance to DV_{CC}	400	600	kΩ
25	Conversion Time	t_{CONV}	BUSY Output High Time	-	850	ns
26	$\overline{CS}$ Falling Edge to BUSY ↑	t_{BUSYLH}	C_L = 10pF	-	40	ns
27	SDO Data Valid Delay from BUSY ↓	$t_{DBUSYLSDOV}$	C_L = 10pF	-	0	ns
28	SDO Data Valid Hold Time from SCK ↑	t_{HSDOV}	C_L = 10pF	8	-	ns

Table 3. Reported Parameters (Cont.)

Figure	Parameter	Symbol	Conditions	Low Limit	High Limit	Unit
29	SDO Bus Acquisition Time from $\overline{CS}$ ↓	$t_{DCSLSDOL}$	C_L = 10pF	-	30	ns
30	SDO Bus Relinquish Time after $\overline{CS}$ ↑	$t_{DCSHSDOZ}$	C_L = 10pF	-	30	ns

Related Information

For a full list of related documents, visit our website:

- ISL73141SEH device page
- MIL-STD-883 test method 1017

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