HS-565BRH

Neutron Testing of the HS-565BRH Digital-to-Analog Converter

Introduction

This report summarizes results of 1MeV equivalent neutron testing of the HS-565BRH radiation hardened 12-bit digital-to-analog converter (DAC). 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^{14}n/cm^2. These results also apply to the HS-565BEH.

Product Description

The HS-565BxH is a radiation hardened 12-bit digital-to-analog converter (DAC). The monolithic chip includes a precision voltage reference, a thin-film resistor R-2R ladder network, a reference control amplifier, and twelve high-speed bipolar current switches. The part is implemented in a dielectrically isolated process that provides latch-up free operation and minimizes parasitic capacitance and leakage currents. Ground currents are also minimized, which produces a low and constant current through the ground terminal, reducing errors caused by code-dependent ground currents. The HS-565BxH is laser trimmed at the die level for a maximum integral nonlinearity error of ±0.25LSB at room temperature. In addition, the low noise on-chip buried Zener diode reference is trimmed both for absolute value and minimum temperature coefficient. The pinout for the HS-565BxH is shown in Figure 1.

HS9-565BRH, HS9-565BEH
MIL-STD-1835 CDFP4-F24
(Ceramic Flatpack)
Top View

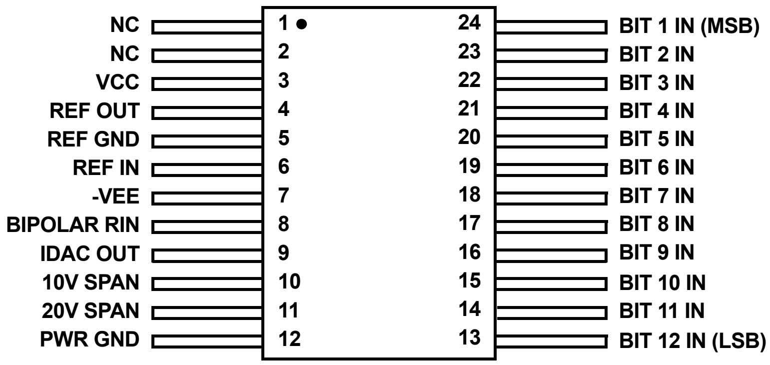

Figure 1. HS-565BxH Package and Pin Configuration

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1. Test Description

1.1 Irradiation Facility

Neutron fluence irradiations were performed on the test samples on August 31, 2021, 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, 1×10^{13}n/cm^2, and 1×10^{14}n/cm^2. As the 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. HS-565BxH 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
CRF#62106-D	1.00E+14	1000	1235	8.10E+10	14067	1.15E+14

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, five to be irradiated at 1×10^{13}n/cm^2, and five to be irradiated at 1×10^{14}n/cm^2. The actual levels achieved, which are shown in Table 1, were 5.4×10^{11}n/cm^2, 2.1×10^{12}n/cm^2, 1.1×10^{13}n/cm^2, and 1.2×10^{14}n/cm^2. Three control units were used.

The 20 HS-565BRH samples were drawn from Lot G0J4HEA. Samples were packaged in the standard hermetic 24-lead ceramic (CDFP) production package. Samples were processed through burn-in before irradiation and were screened to the SMD limits at room, low, and high temperatures before the start of neutron testing.

2. Results

Neutron testing of the HS-565BxH 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 summarizes the results of the neutron testing. All samples passed at levels up to and including 1.14×10^{13}n/cm^2, and while all five units remained functional at 1.15×10^{14}n/cm^2, they all failed some parameters.

Table 2. HS-565BxH Attributes Data

1 MeV 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
1×10^{14}	1.15×10^{14}	5	0	5	All failed

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

2.2 Key Parameter Variables Data

The plots in Figure 2 through Figure 17 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. Each marker represents a different set of five samples. The line connecting them makes the graph easier to read. The plots also include error bars at each downpoint, 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 SMD are also shown, these limits are provided for guidance only as the HS-565BxH is not specified for the neutron environment.

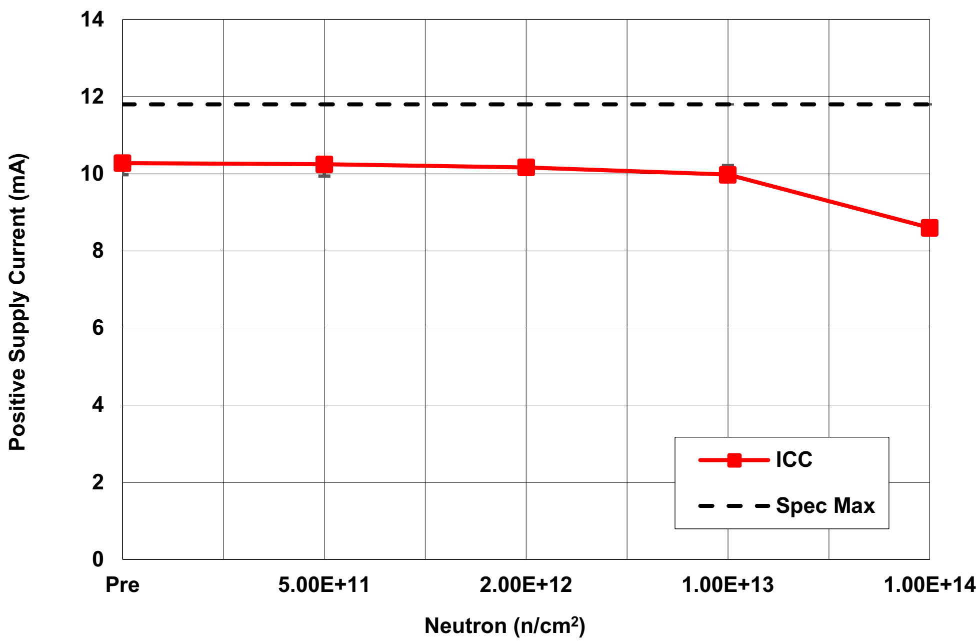

Figure 2. HS-565BxH positive power supply current (I_{CC}) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limit is 11.8mA maximum.

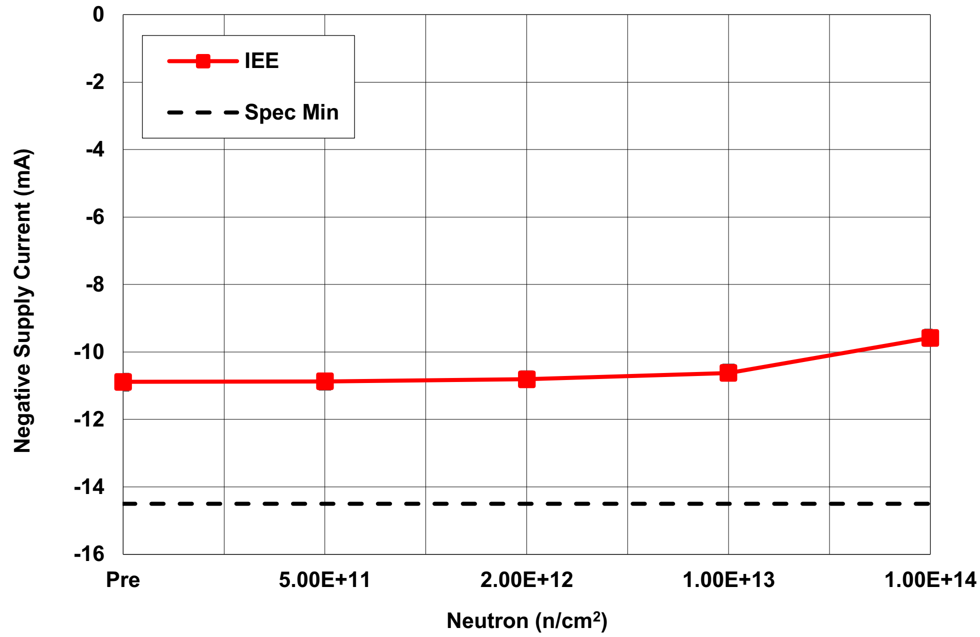

Figure 3. HS-565BxH negative power supply current (I_{EE}) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limit is -14.5mA minimum.

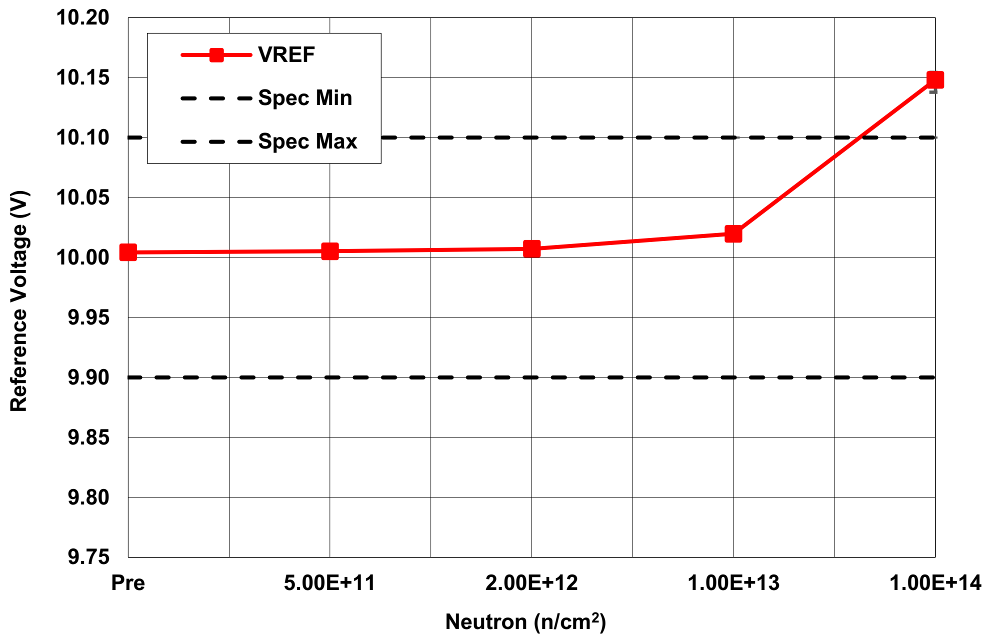

Figure 4. HS-565BxH reference voltage (V_{REF_OUT}) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are 9.9V minimum and 10.1V maximum.

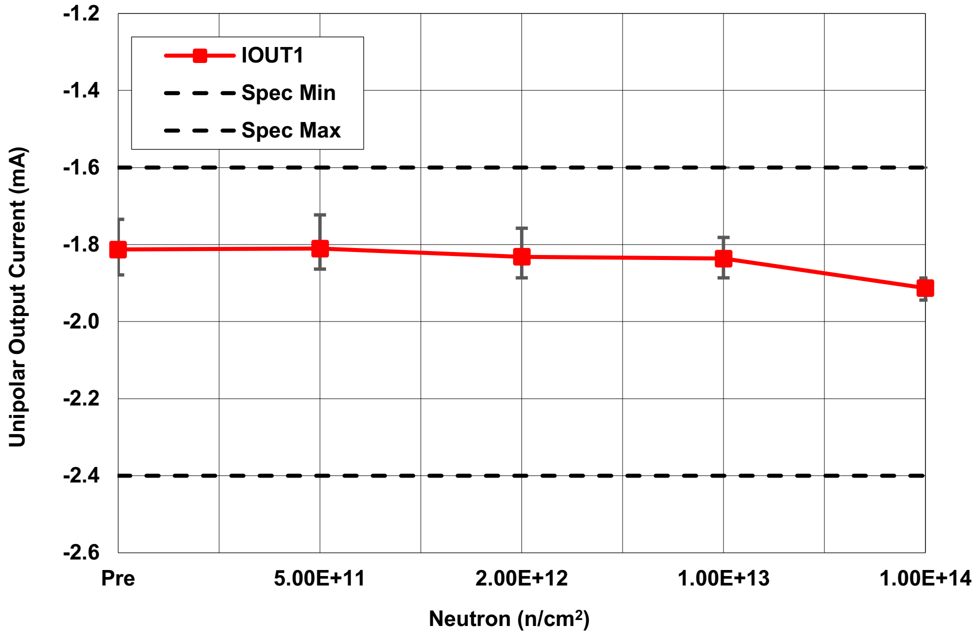

Figure 5. HS-565BxH unipolar output current (I_{OUT1}) with all bits on, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are -2.4mA minimum and -1.6mA maximum.

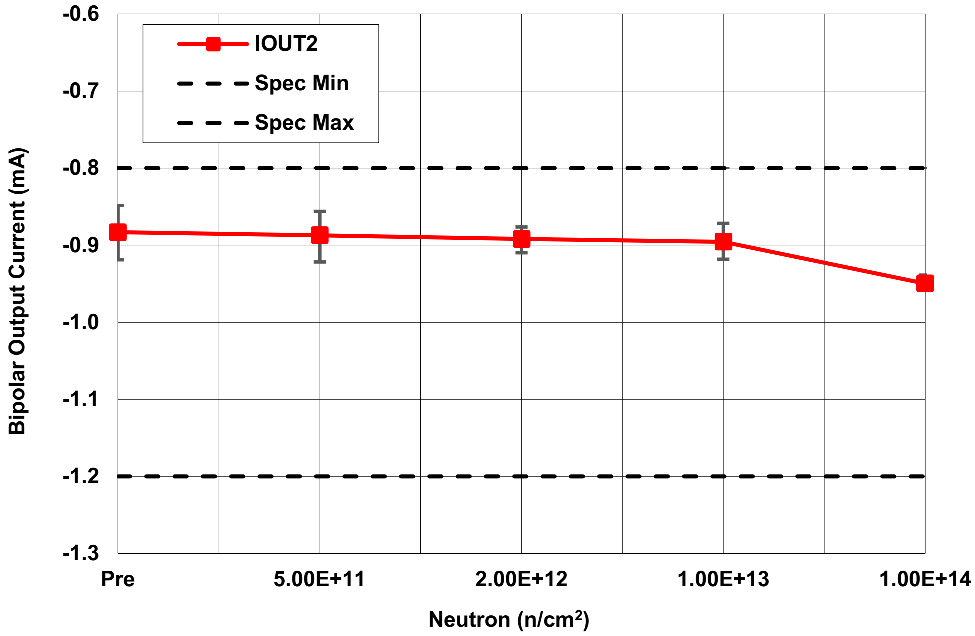

Figure 6. HS-565BxH bipolar output current (I_{OUT2}) with all bits on or off, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are -1.2mA minimum and -0.8mA maximum.

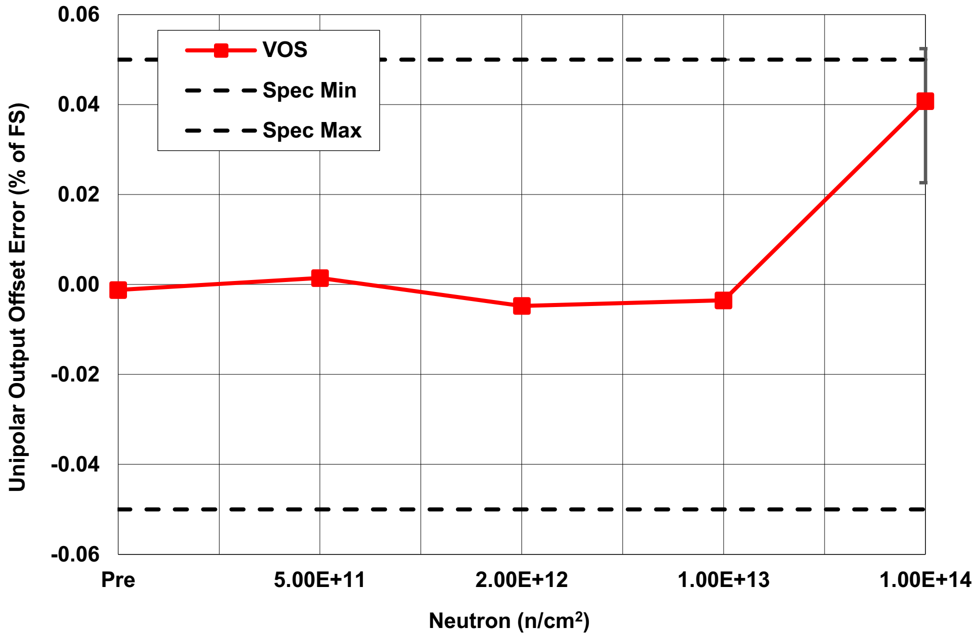

Figure 7. HS-565BxH unipolar output offset error (V_{OS}) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are -0.05% of F.S minimum and 0.05% of F.S. maximum.

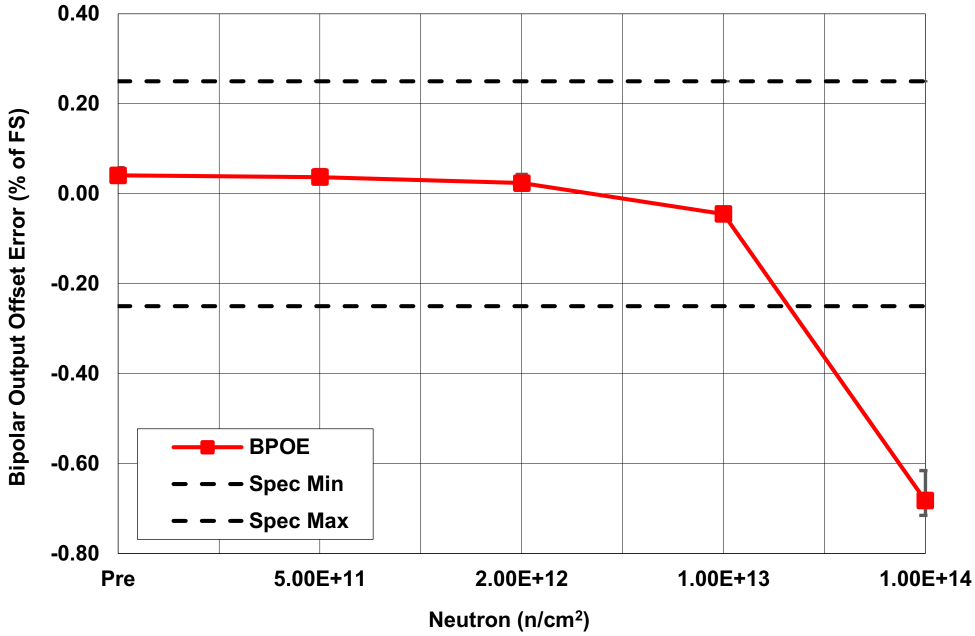

Figure 8. HS-565BxH bipolar output offset error (BPOE) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are -0.05% of F.S minimum and 0.05% of F.S. maximum.

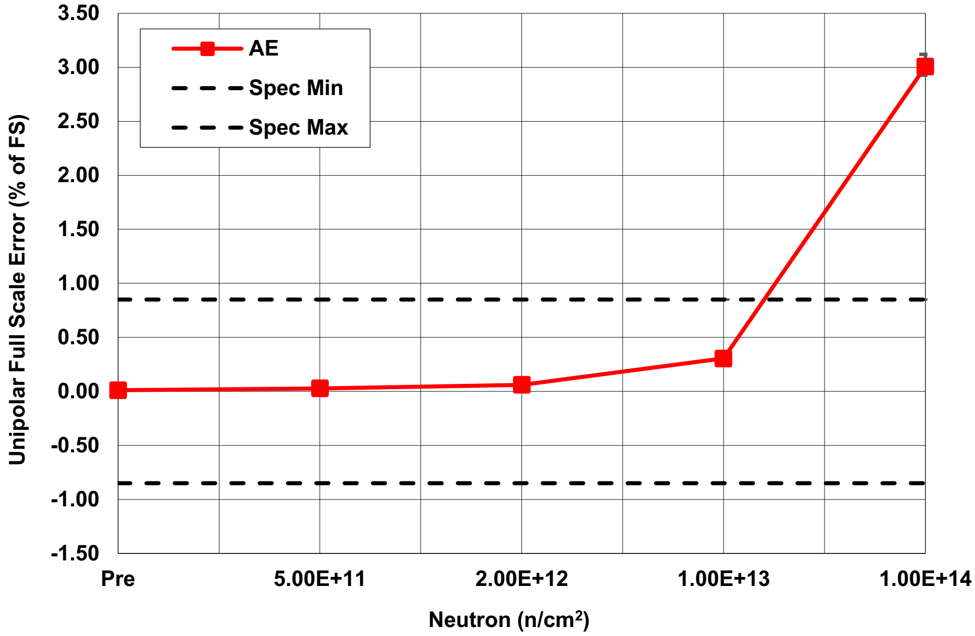

Figure 9. HS-565BxH unipolar full scale error (AE) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are -0.85% of F.S minimum and 0.85% of F.S. maximum.

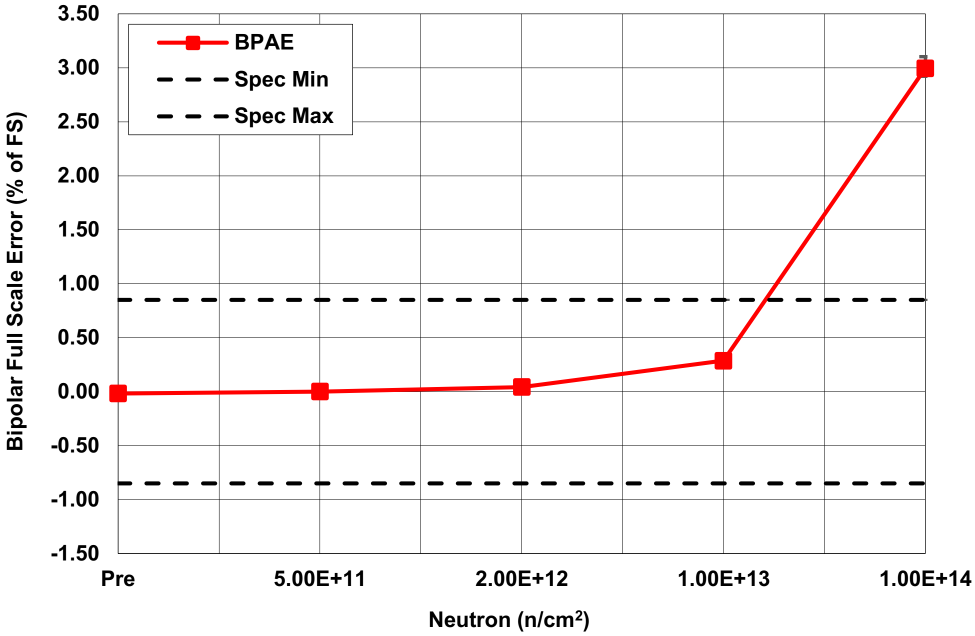

Figure 10. HS-565BxH bipolar full scale error (BPAE) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are -0.85% of F.S minimum and 0.85% of F.S. maximum.

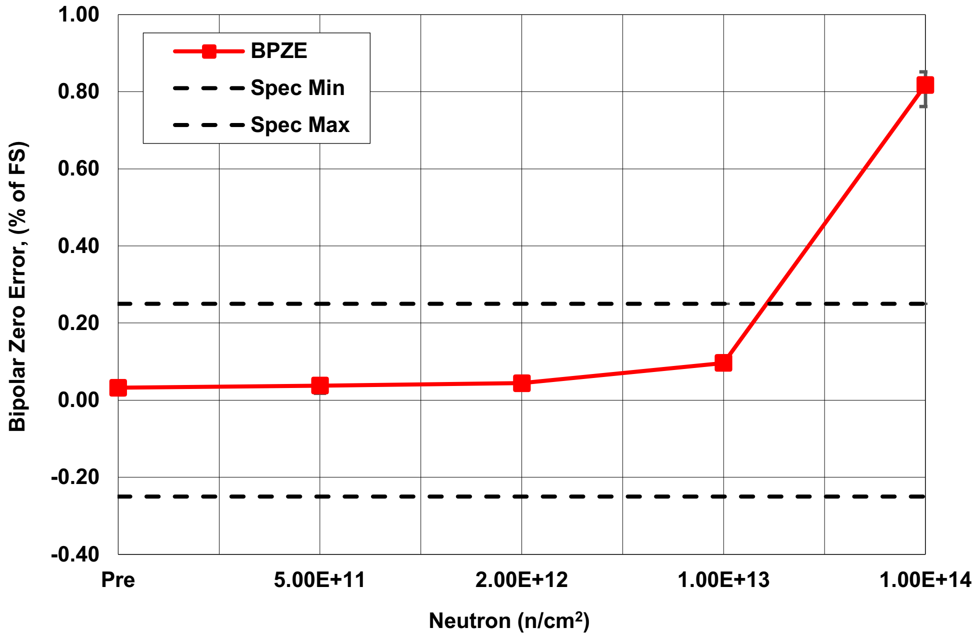

Figure 11. HS-565BxH bipolar zero error (BPZE) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are -0.25% of F.S minimum and 0.25% of F.S. maximum.

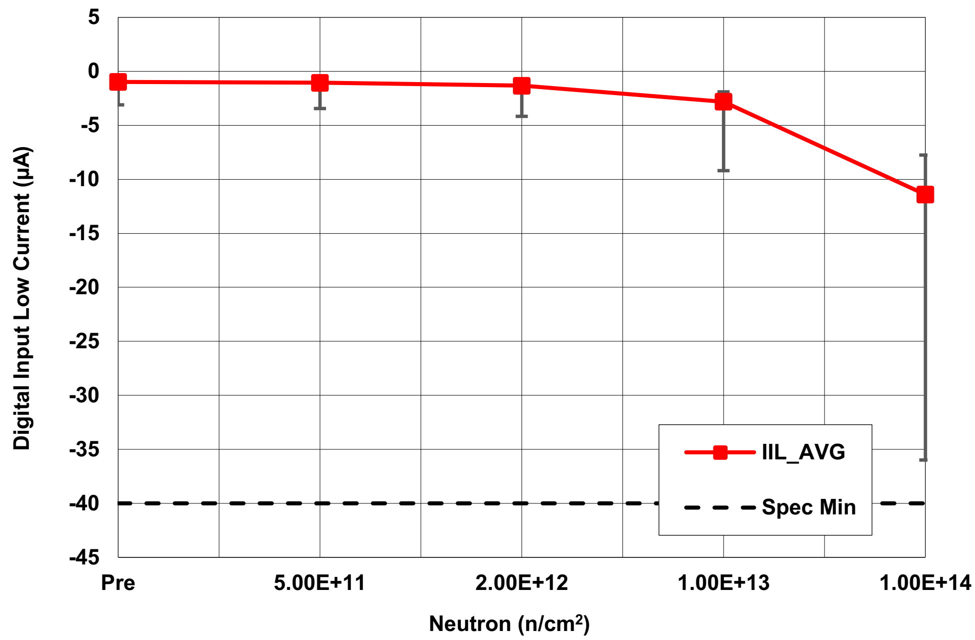

Figure 12. HS-565BxH average digital input LOW current (I_{IL}) with V_{IN} = 0V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limit is -40µA minimum.

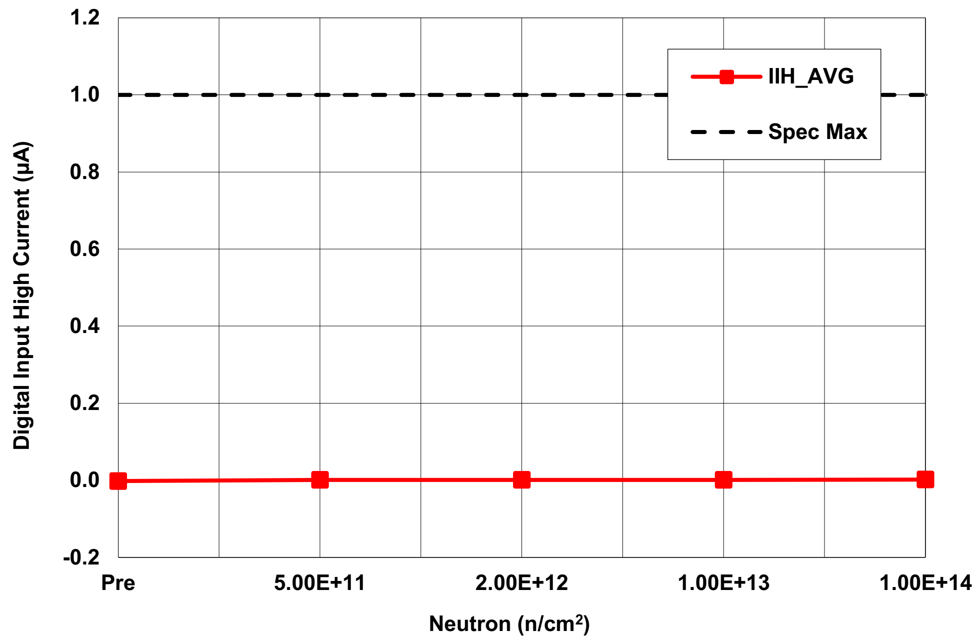

Figure 13. HS-565BxH average digital input HIGH current (I_{IH}) with V_{IN} = 5.5V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limit is 1µA maximum.

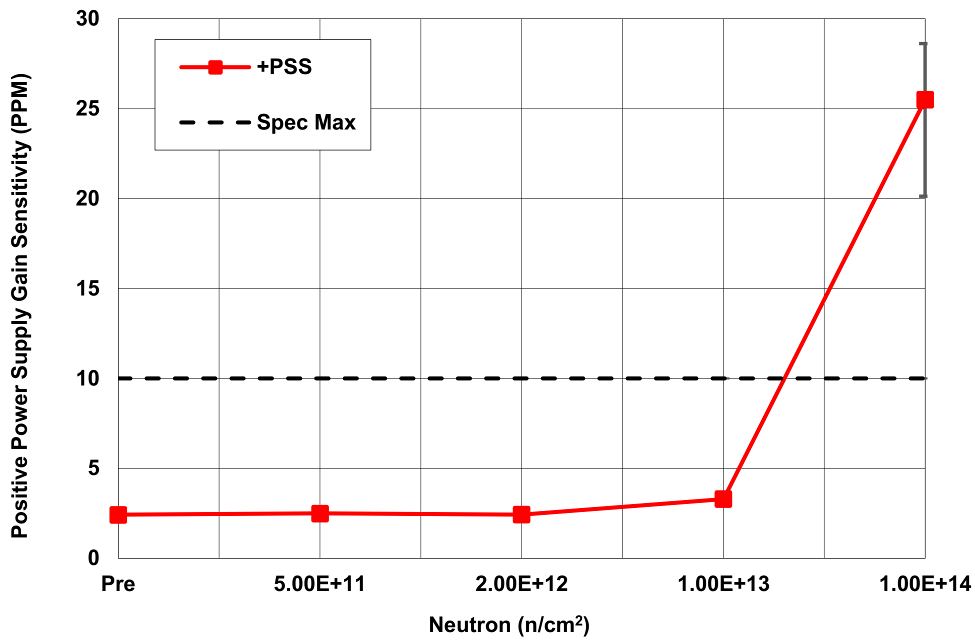

Figure 14. HS-565BxH positive power supply gain sensitivity (+PSS) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limit is 10(PPM of full scale)/(%ΔV_{CC}) maximum.

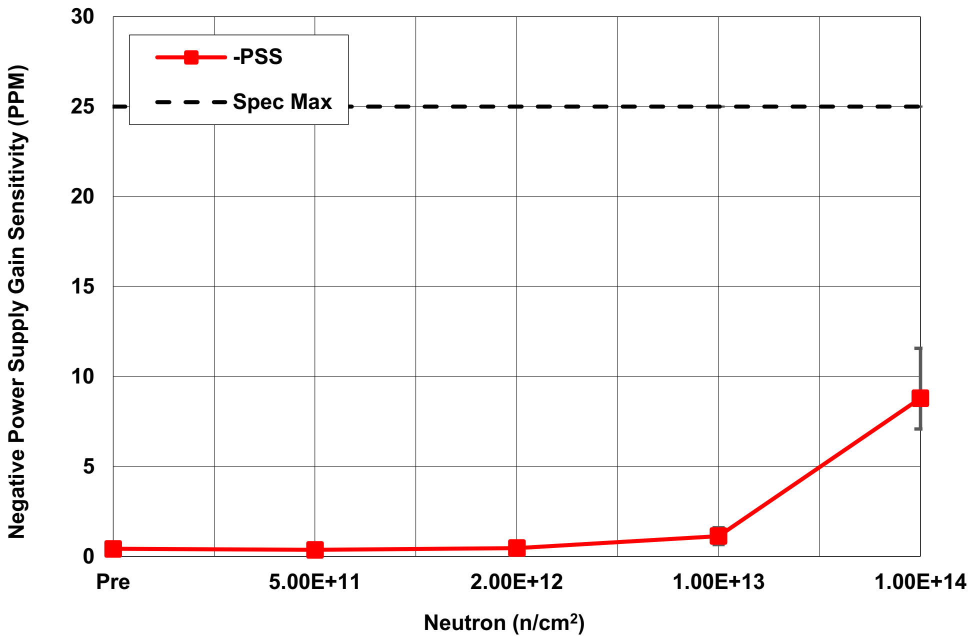

Figure 15. HS-565BxH negative power supply gain sensitivity (-PSS) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limit is 25(PPM of full scale)/(%ΔV_{EE}) maximum.

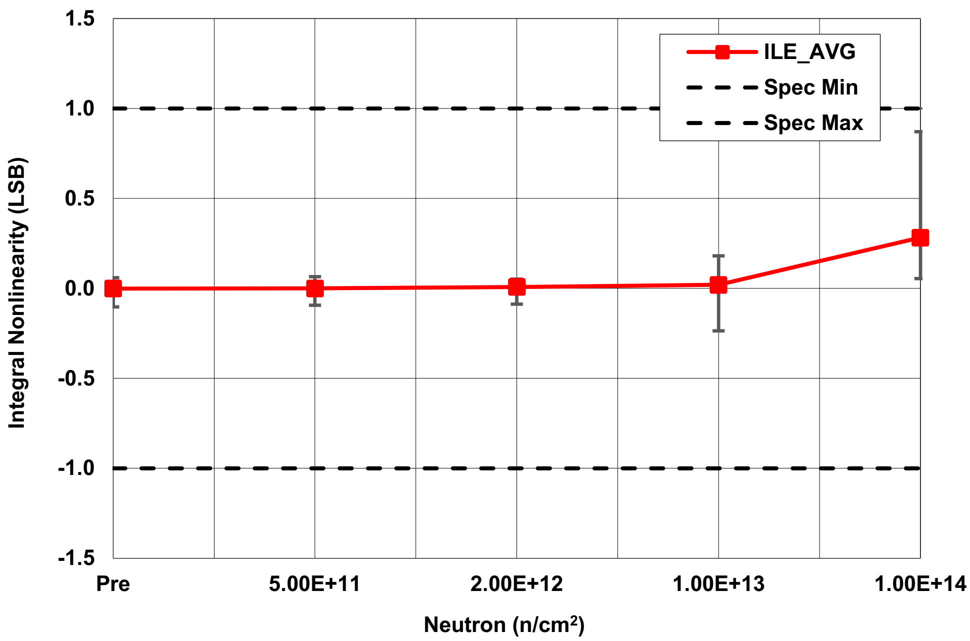

Figure 16. HS-565BxH average integral nonlinearity (ILE) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are -1 LSB minimum and 1 LSB maximum.

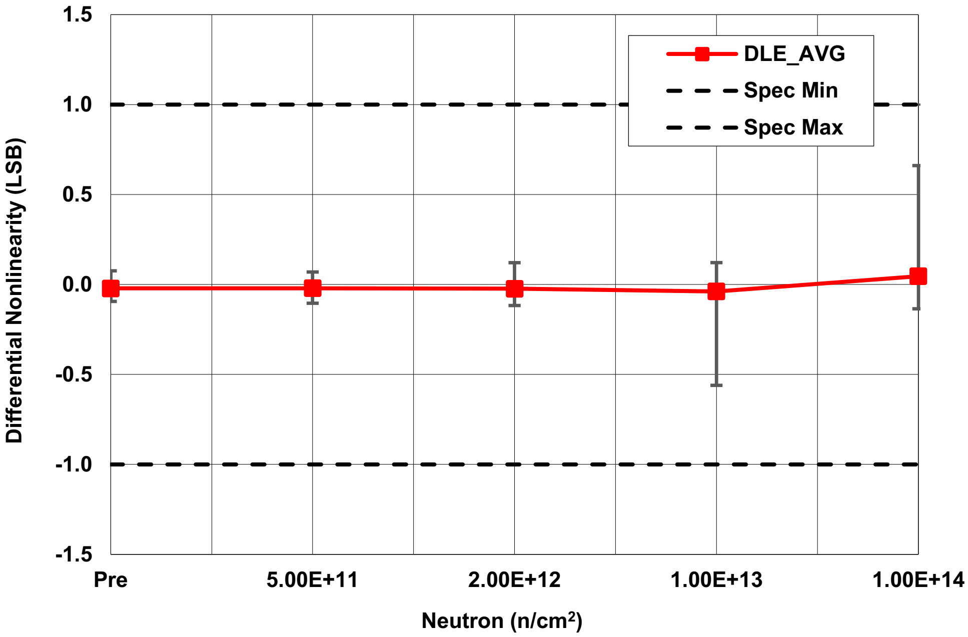

Figure 17. HS-565BxH average differential nonlinearity (DLE) with V_{CC} = +15V, V_{EE} = -15V, following irradiation to each level. The error bars (if visible) represent the minimum and maximum measured values. The post-irradiation SMD limits are -1 LSB minimum and 1 LSB maximum.

3. Discussion and Conclusion

The results of 1MeV equivalent neutron testing of the HS-565BxH radiation-hardened 12-bit digital-to-analog converter (DAC) were reported. Parts were tested at actual fluences of 5.4×10^{11}n/cm^2, 2.1×10^{12}n/cm^2, 1.1×10^{13}n/cm^2, and 1.2×10^{14}n/cm^2. The results of key parameters before and after irradiation to each level are plotted in Figure 2 through Figure 17. 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 SMD, but it should be noted that these limits are provided for guidance only as the HS-565BxH is not specified for the neutron environment.

All samples passed the post-irradiation SMD limits after all exposures up to and including 1.1×10^{13}n/cm^2. All samples remained functional but failed some parameters to the post-irradiation SMD limits after 1.2×10^{14}n/cm^2.

4. Revision History

Revision	Date	Description
1.00	Jul 11, 2022	Initial release.

Appendix

Table 3 lists the key parameters that are considered indicative of part performance. These parameters are plotted in Figure 2 through Figure 17. All limits are taken from the HS-565BxH SMD.

Table 3. HS-565BxH Key Total Dose SMD Parameters (T_A = 25°C)

Fig.	Parameter	Symbol	Conditions	Low Limit	High Limit	Units
2	Positive Power Supply Current	I_{CC}	V_{CC} = +15V, V_{EE} = -15V		11.8	mA
3	Negative Power Supply Current	I_{EE}	V_{CC} = +15V, V_{EE} = -15V	-14.5		mA
4	Reference Voltage	V_{REF_OUT}	V_{CC} = +15V, V_{EE} = -15V	9.9	10.1	V
5	Unipolar Output Current	I_{OUT1}	All bits on	-2.4	-1.6	mA
6	Bipolar Output Current	I_{OUT2}	All bits on or off	-1.2	-0.8	mA
7	Unipolar Output Offset Error	V_{OS}	V_{CC} = +15V, V_{EE} = -15V	-0.05	0.05	% of F.S.
8	Bipolar Output Offset Error	BPOE	V_{CC} = +15V, V_{EE} = -15V	-0.05	0.05	% of F.S.
9	Unipolar Full Scale Error	AE	V_{CC} = +15V, V_{EE} = -15V	-0.85	0.85	% of F.S.
10	Bipolar Full Scale Error	BPAE	V_{CC} = +15V, V_{EE} = -15V	-0.85	0.85	% of F.S.
11	Bipolar Zero Error	BPZE	V_{CC} = +15V, V_{EE} = -15V	-0.85	0.85	% of F.S.
12	Digital Input LOW Current	I_{IL}	V_{IN} = 0V		1	µA
13	Digital Input HIGH Current	I_{IH}	V_{IN} = 5.5V	-40		µA
14	Positive Power Supply Gain Sensitivity	+PSS	V_{CC} = +15V; V_{EE} = -15V		10	(ppm of F.S.)/(%ΔV_{CC})
15	Negative Power Supply Gain Sensitivity	-PSS	V_{CC} = +15V; V_{EE} = -15V		25	(ppm of F.S.)/(%ΔV_{EE})
16	Integral Nonlinearity	ILE	V_{CC} = +15V, V_{EE} = -15V	-1	1	LSB
17	Differential Nonlinearity	DLE	V_{CC} = +15V, V_{EE} = -15V	-1	1	LSB

Related Information

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

- HS-565BRH, HS-565BEH device pages
- MIL-STD-883 Test Method 1017

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Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information

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