HS-1825ARH

Neutron Testing

TR032
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Introduction

This report summarizes results of 1MeV equivalent neutron testing of the HS-1825ARH voltage mode Pulse Width Modulator (PWM). 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
- HS-1825ARH Datasheet
- DSCC Standard Microcircuit Drawing (SMD) 5962-99558

Part Description

The radiation hardened HS-1825ARH and HS-1825AEH pulse width modulators are designed to be used in high frequency switched-mode power supplies and can be used in either current-mode or voltage-mode. They are well suited for single-ended boost converter applications. Device features include a precision voltage reference, low power start-up circuit, high frequency oscillator, wide-band error amplifier and a fast current-limit comparator. The HS-1825ARH and HS-1825AEH are fabricated in the Intersil Radiation Hardened Silicon Gate (RSG) dielectrically isolated BiCMOS process. Table 1 shows the pinout of the part.

Detailed electrical specifications for these devices are contained in SMD 5962-99558. Specifications for radiation hardened QML devices are controlled by the Defense Logistics Agency Land and Maritime (DLA).

The HS-1825ARH is acceptance tested on a wafer-by-wafer basis to a total dose level of 300krad(Si) at high dose rate (50-300rad(Si)/s). The IS-1845AEH is acceptance tested to 300krad(Si) at high dose rate (50-300rad(Si)/s) and to 50krad(Si) at low dose rate (< 0.01rad(Si)/s).

TABLE 1. HS-1825ARH PIN ASSIGNMENTS (16-PIN FLATPACK)

TERMINAL NUMBER	TERMINAL SYMBOL	TERMINAL NUMBER	TERMINAL SYMBOL
1	INV	9	ILIM/SD
2	NON-INV	10	GND
3	E/A OUT	11	OUTPUT A
4	CLOCK	12	POWER GND
5	RT	13	VC
6	CT	14	OUTPUT B
7	RAMP	15	VCC
8	SOFT-START	16	VREF 5.1V

Test Description

Irradiation Facilities

1MeV equivalent neutron irradiation was performed by the Boeing team at the Survivability and Vulnerability Assessment Directorate, US Army, White Sands Missile Range fast burst reactor (White Sands Missile Range, NM 88002). 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 Intersil for electrical testing.

Test Fixturing

No formal irradiation test fixturing was involved. These DD tests are termed “bag tests” in the sense that the parts are irradiated in an inactive state with all leads shorted together.

Characterization Equipment and Procedures

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

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. The HS-1825ARH samples were drawn from fabrication lot E0A4PDB and were packaged in the standard 16 Ld ceramic production package. Samples were screened to the SMD limits over temperature before the start of neutron testing.

Results

Neutron testing of the HS-1825ARH 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.

Attributes Data

TABLE 2. HS-1825ARH ATTRIBUTES DATA

PART	SAMPLE SIZE	FLUENCE, n/cm^2	PASS (Note 1)	FAIL	NOTES
HS-1825ARH	5	$2x10^{12}$	5	0	All passed
HS-1825ARH	5	$1x10^{13}$	5	0	All passed
HS-1825ARH	5	$3x10^{13}$	0	5	All failed, start timing, ramp offset, charge current
HS-1825ARH	5	$1x10^{14}$	0	5	All failed, nonfunctional

NOTE:

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

Variables Data

The plots in Figures 1 through 23 show data plots for key parameters before and after irradiation to each level. The reported parameters and their data sheet limits are shown in Table 3. As indicated in Table 2 all samples were nonfunctional after exposure to $1x10^{14}n/cm^2$; for several of the figures, we elected to not plot the data at this level as it has little meaning (being nothing more than an ATE overrange) 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 and minimum error 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; it should be carefully noted that these limits are provided for *guidance only* as the HS-1825ARH is not specified or guaranteed for the neutron environment. Intersil does not design, qualify or guarantee its parts for the DD environment, but has performed limited collaborative neutron testing for customer guidance.

Variables Data Plots

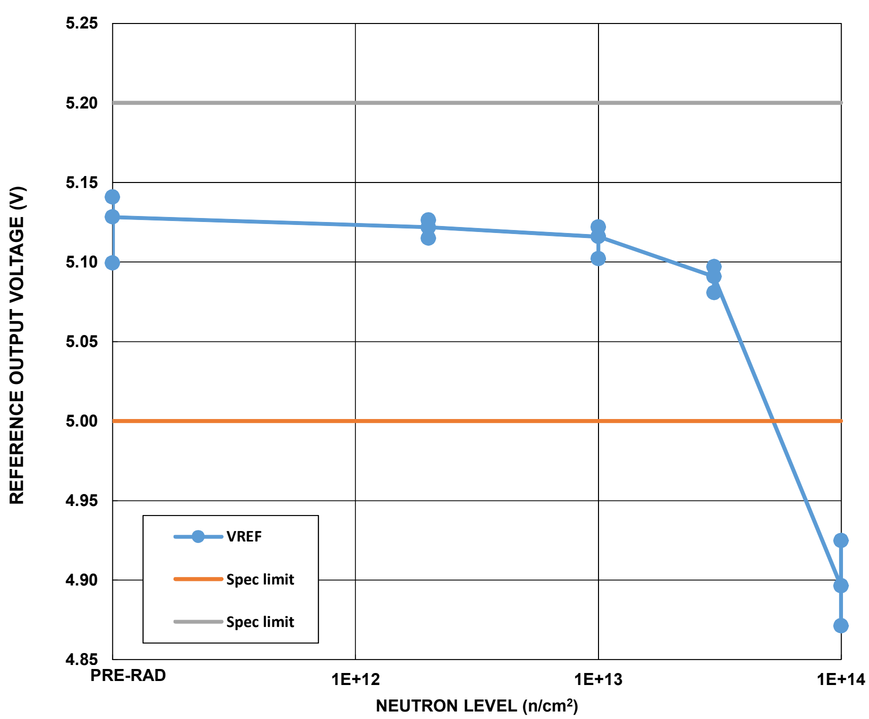

FIGURE 1. HS-1825ARH reference output voltage as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 5V to 5.2V.

Variables Data Plots (Continued)

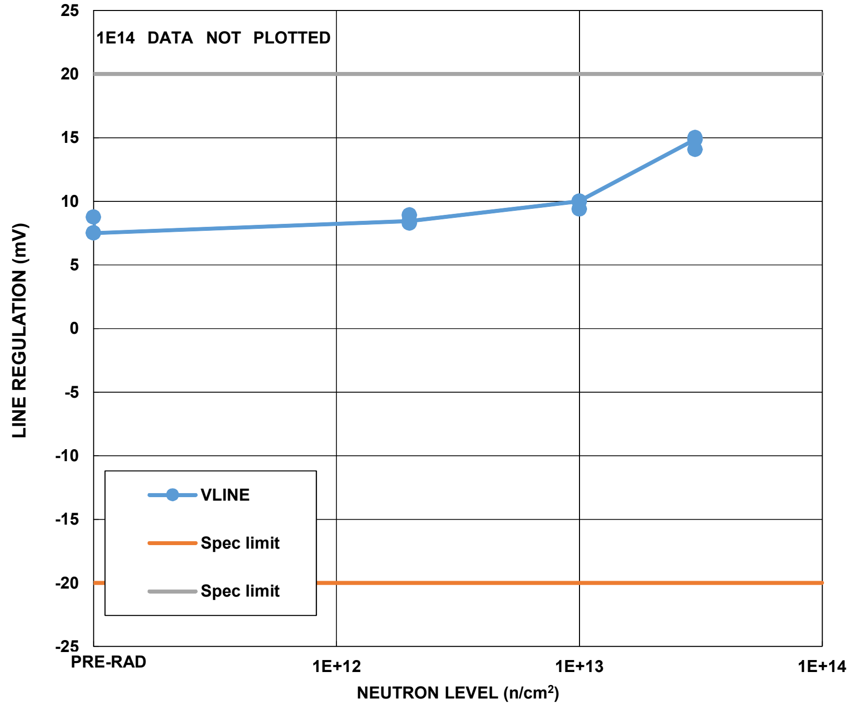

FIGURE 2. HS-1825ARH reference section line regulation as a function of 1MeV equivalent neutron irradiation at $2x10^{12}$ n/cm^2, $1x10^{13}$n/cm^2, $3x10^{13}$n/cm^2 and $1x10^{14}$n/cm^2. The plot shows the population median and minimum and maximum error bars at each downpoint. The $1x10^{14}$n/cm^2 data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are -20mV to 20mV.

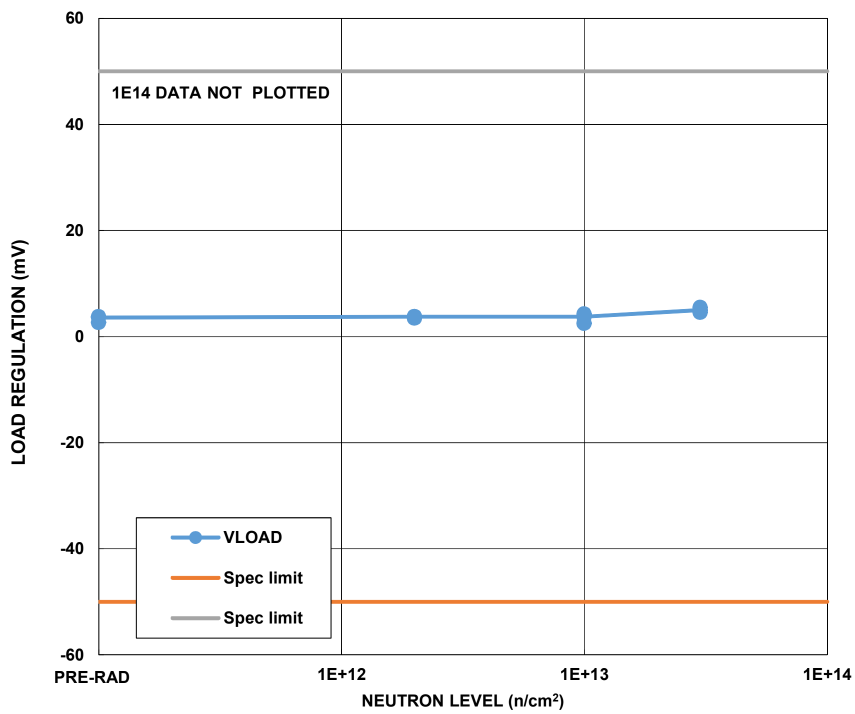

FIGURE 3. HS-1825ARH reference section load regulation as a function of 1MeV equivalent neutron irradiation at $2x10^{12}$n/cm^2, $1x10^{13}$n/cm2, 3 x 1013 n/cm^2 and $1x10^{14}$n/cm^2. The plot shows the population median and minimum and maximum error bars at each downpoint. The $1x10^{14}$n/cm^2 data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are -50mV to 50mV.

Variables Data Plots (Continued)

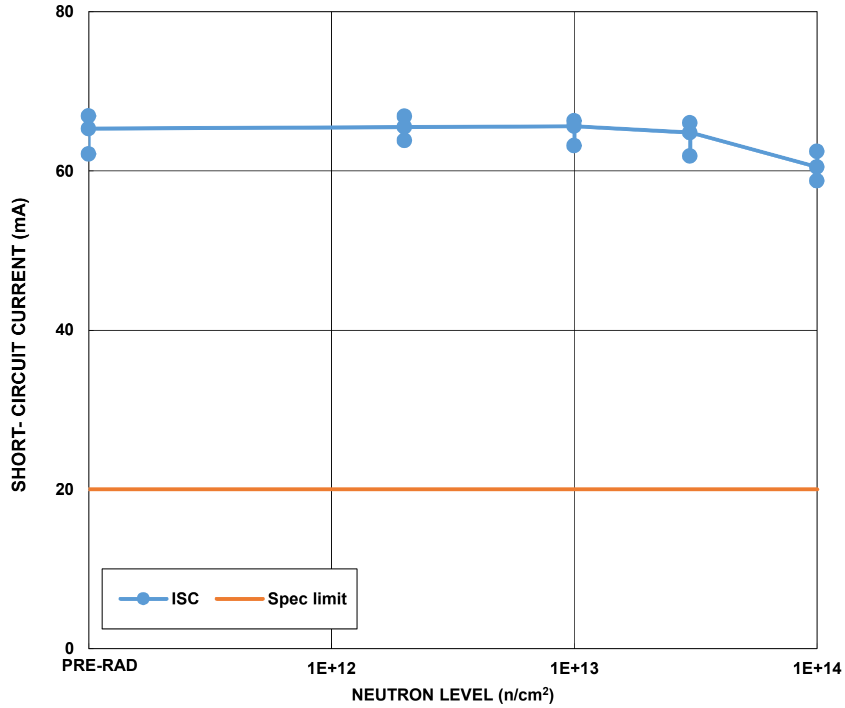

FIGURE 4. HS-1825ARH reference section output short-circuit current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 20mA minimum

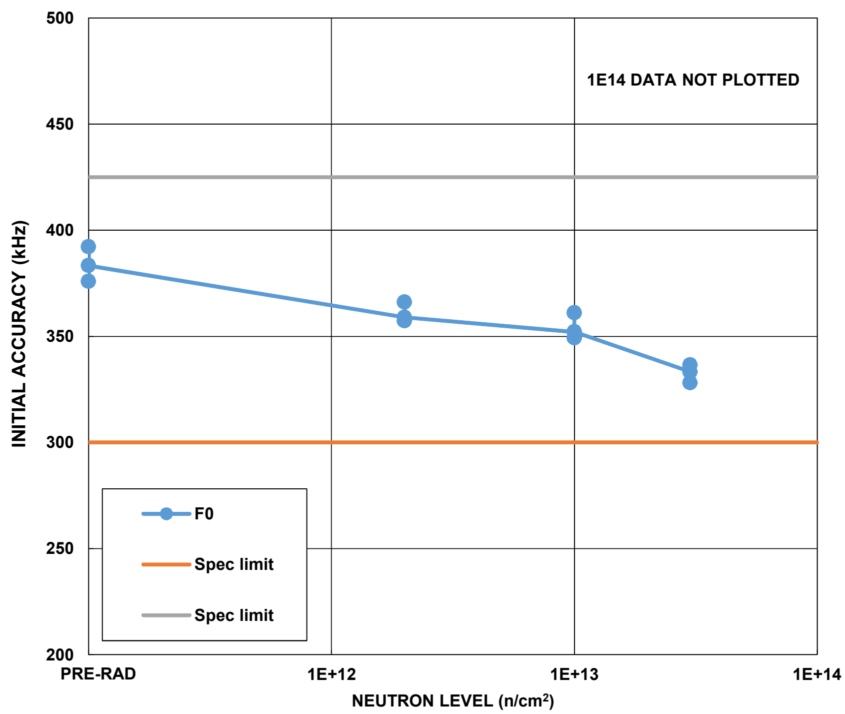

FIGURE 5. HS-1825ARH oscillator section initial accuracy as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The $1x10^{14}n/cm^2$ data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 300kHz to 425kHz.

Variables Data Plots (Continued)

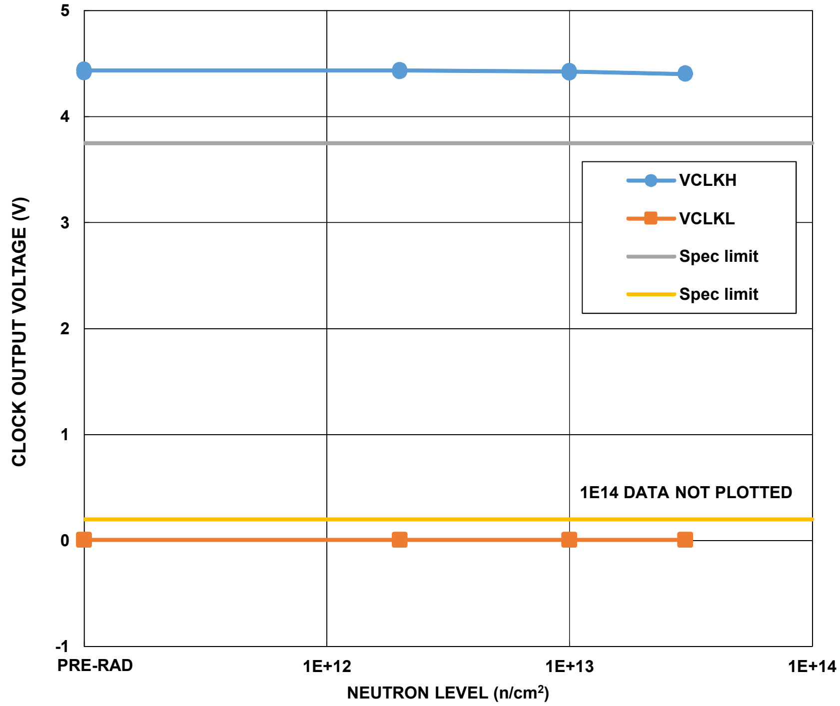

FIGURE 6. HS-1825ARH HIGH and LOW clock output voltage as a function of 1MeV equivalent neutron irradiation at 2x10^{12}n/cm^2, 1x10^{13}n/cm^2, 3x10^{13}n/cm^2 and 1x10^{14}n/cm^2. The plot shows the population median and minimum and maximum error bars at each downpoint. The 1x10^{14}n/cm^2 data were ATE overranges and are not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 3.75V minimum (HIGH) and 0.2V maximum (LOW).

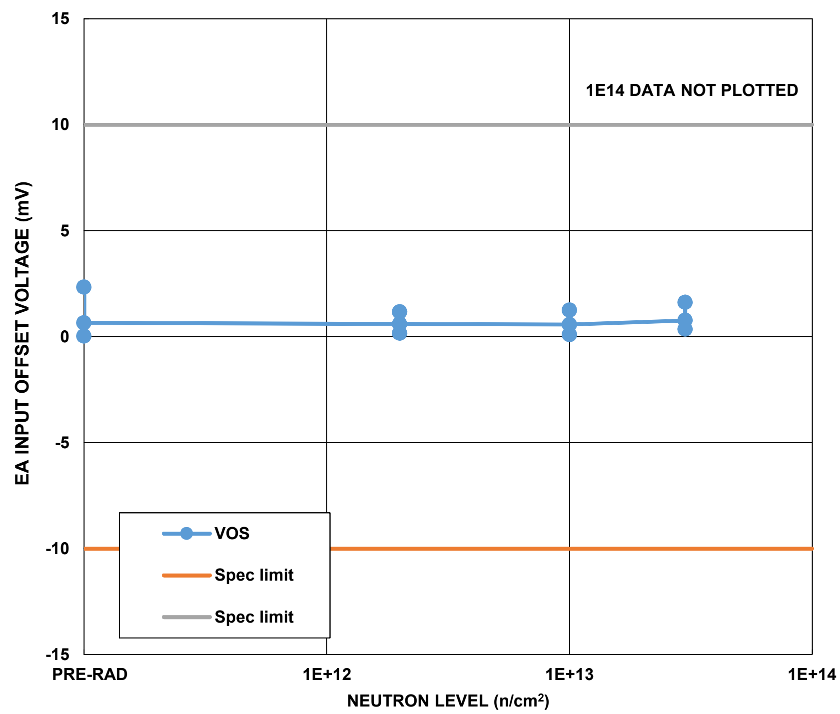

FIGURE 7. HS-1825ARH error amplifier input offset voltage as a function of 1MeV equivalent neutron irradiation at 2x10^{12}n/cm^2, 1x10^{13}n/cm^2, 3x10^{13}n/cm^2 and 1x10^{14}n/cm^2. The plot shows the population median and minimum and maximum error bars at each downpoint. The 1x10^{14}n/cm^2 data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are -10mV to 10mV.

Variables Data Plots (Continued)

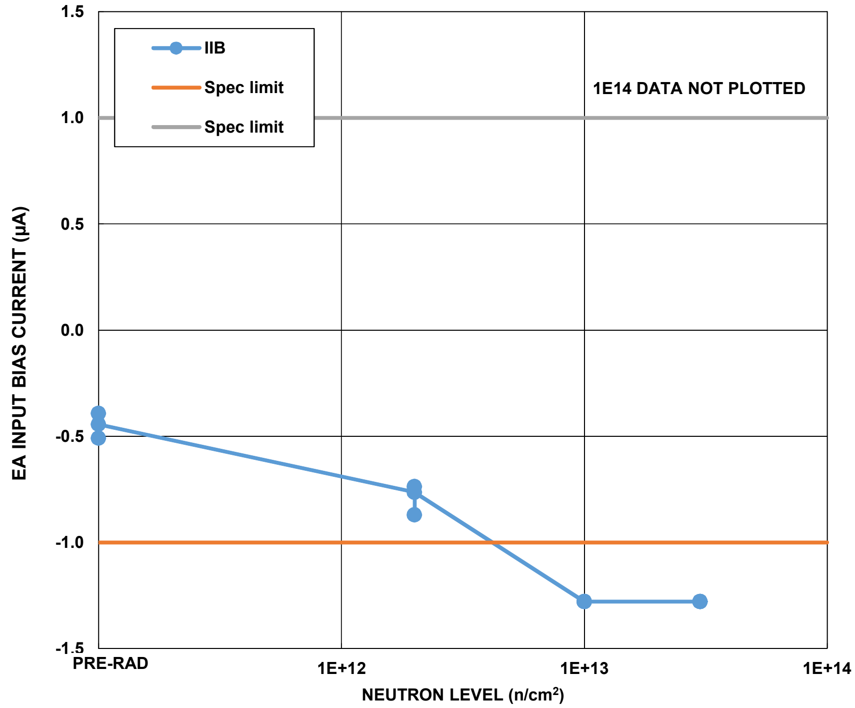

FIGURE 8. HS-1825ARH error amplifier input bias current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The $1x10^{14}n/cm^2$ data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are -1µA to 1µA.

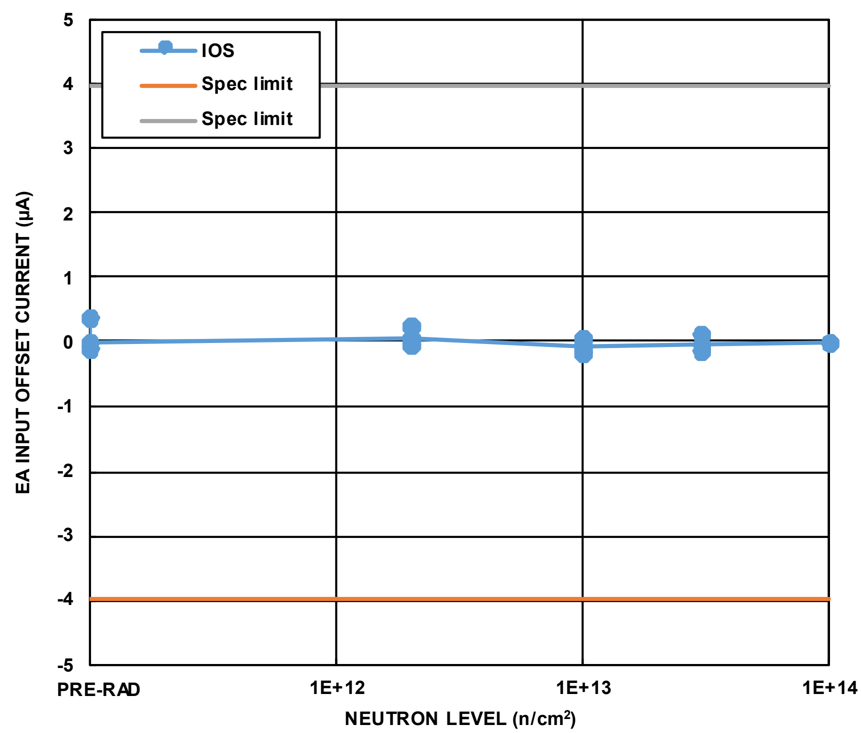

FIGURE 9. HS-1825ARH error amplifier input offset current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limits are -4µA to 4µA.

Variables Data Plots (Continued)

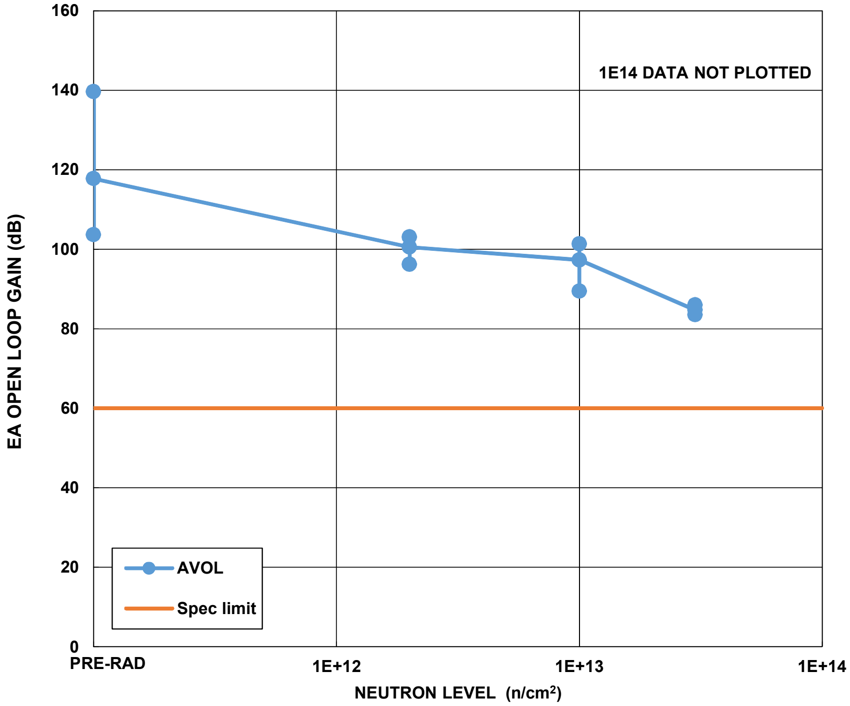

FIGURE 10. HS-1825ARH error amplifier open loop gain as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The $1x10^{14}n/cm^2$ data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 60dB minimum.

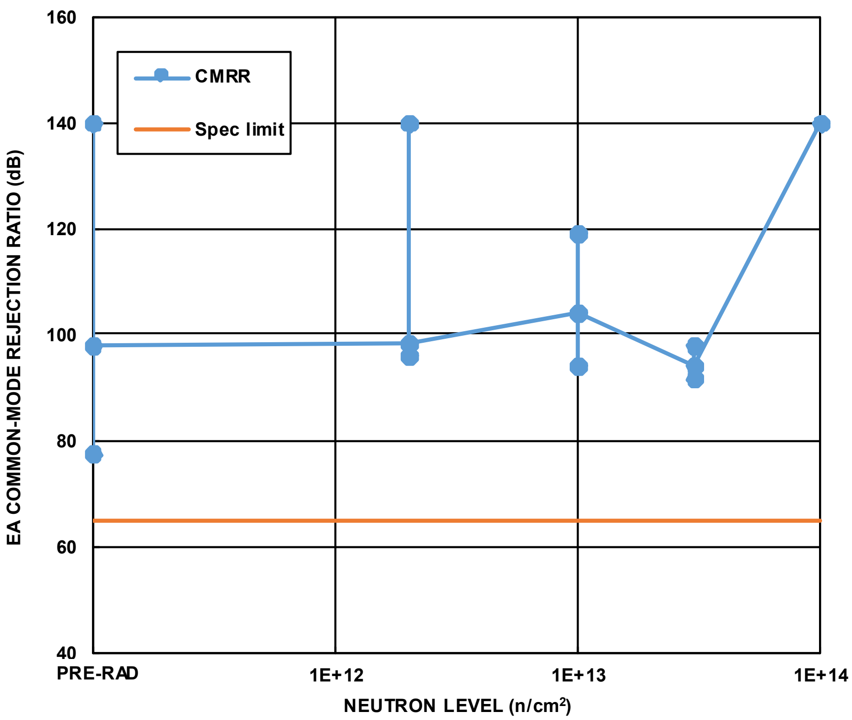

FIGURE 11. HS-1825ARH error amplifier common mode rejection ratio as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 65dB minimum.

Variables Data Plots (Continued)

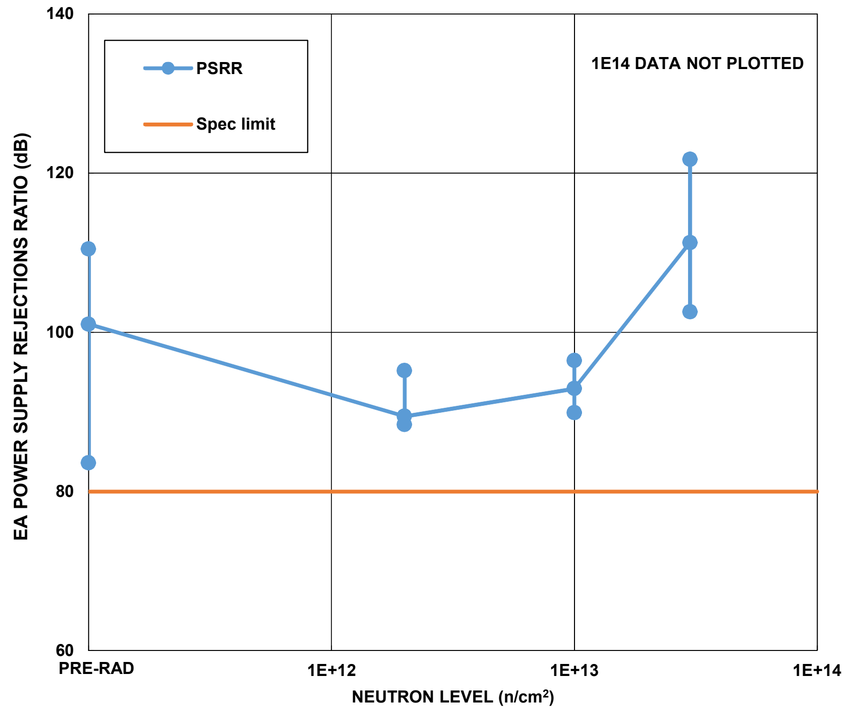

FIGURE 12. HS-1825ARH error amplifier power supply rejection ratio as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The $1x10^{14}n/cm^2$ data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 80dB minimum.

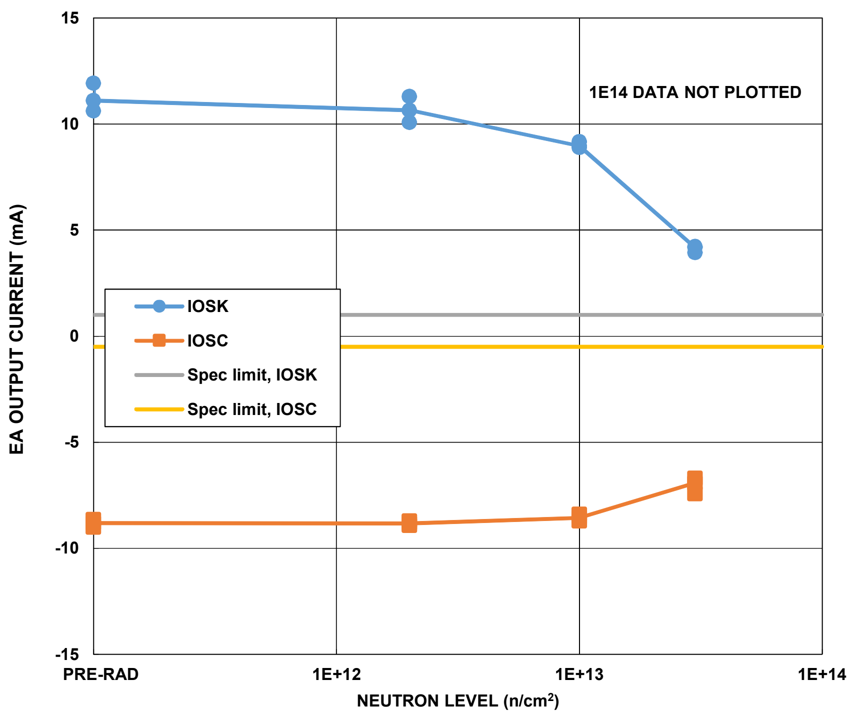

FIGURE 13. HS-1825ARH error amplifier output current, sourcing and sinking, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The $1x10^{14}n/cm^2$ data points were ATE overranges and are not plotted. The post-total dose irradiation SMD limits are 1mA minimum (sinking) and -0.5mA minimum (sourcing).

Variables Data Plots (Continued)

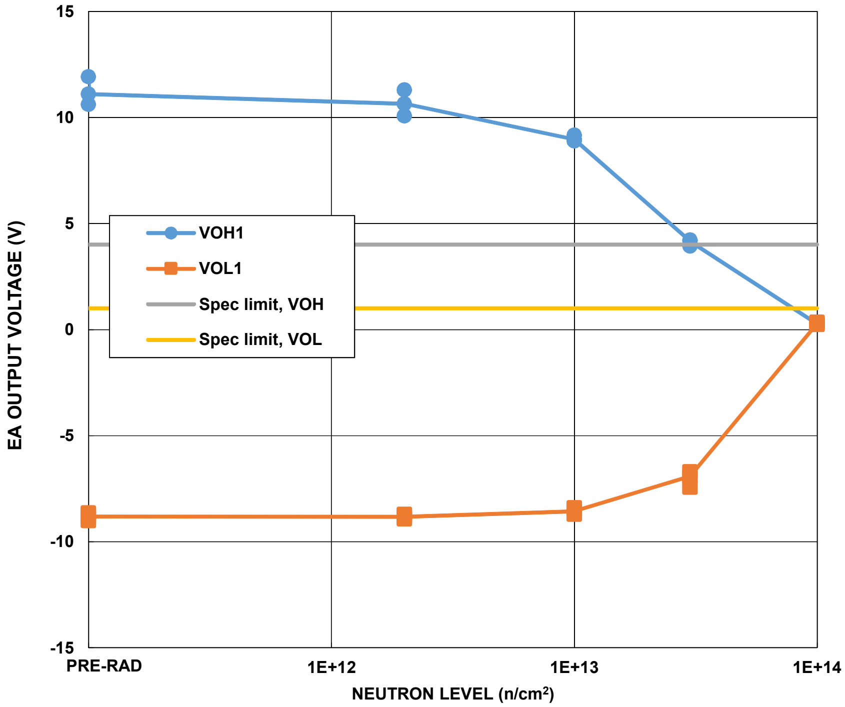

FIGURE 14. HS-1825ARH error amplifier output voltage, HIGH and LOW, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 4V minimum (HIGH) and 1V maximum (LOW).

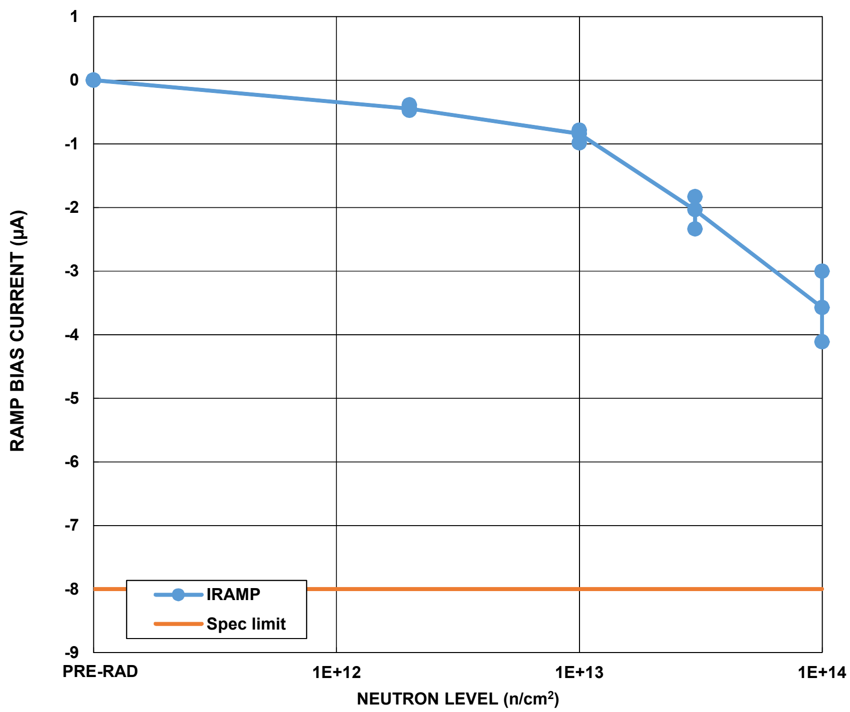

FIGURE 15. HS-1825ARH PWM ramp bias current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}$ n/cm^2, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}$ n/cm^2. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is -8µA minimum.

Variables Data Plots (Continued)

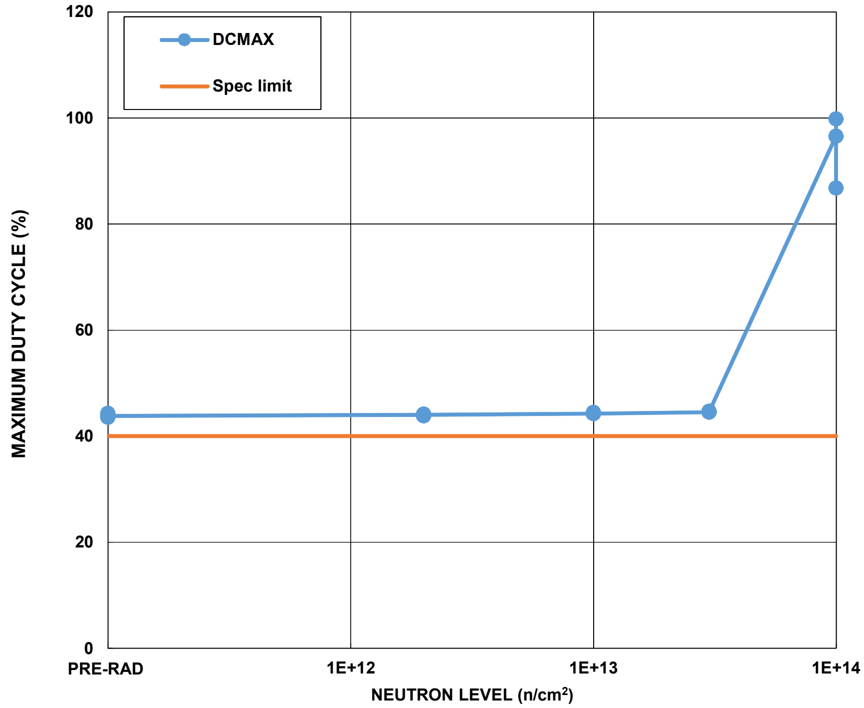

FIGURE 16. HS-1825ARH PWM maximum duty cycle as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 40% minimum.

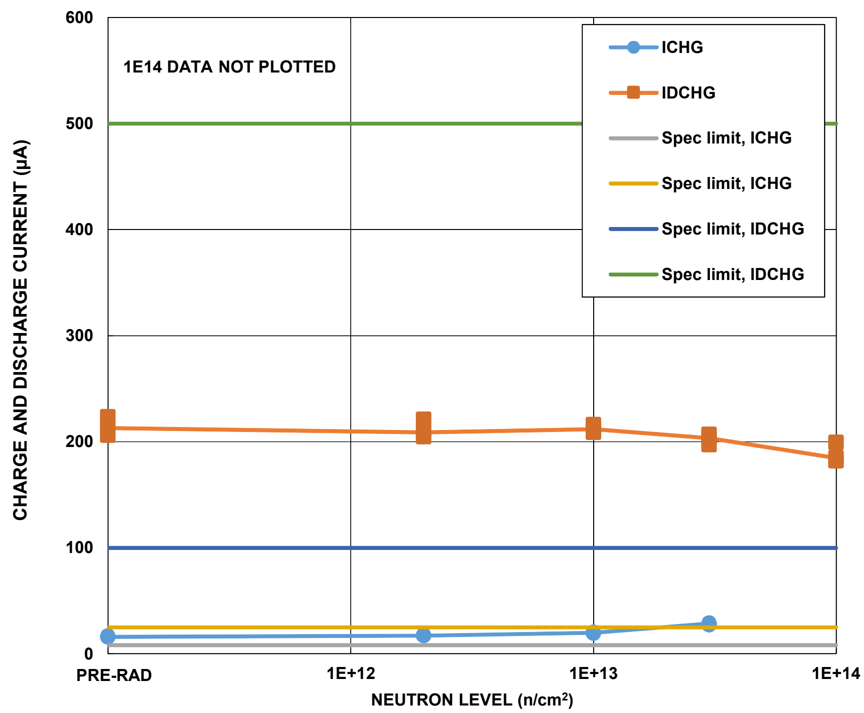

FIGURE 17. HS-1825ARH soft-start charge and discharge current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, 3x $10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The $1x10^{14}n/cm^2$ discharge current data was an ATE overrange and is not plotted. The post-total dose irradiation SMD limits are 8µA to 25µA (charging) and 100µA to 500µA (discharging).

Variables Data Plots (Continued)

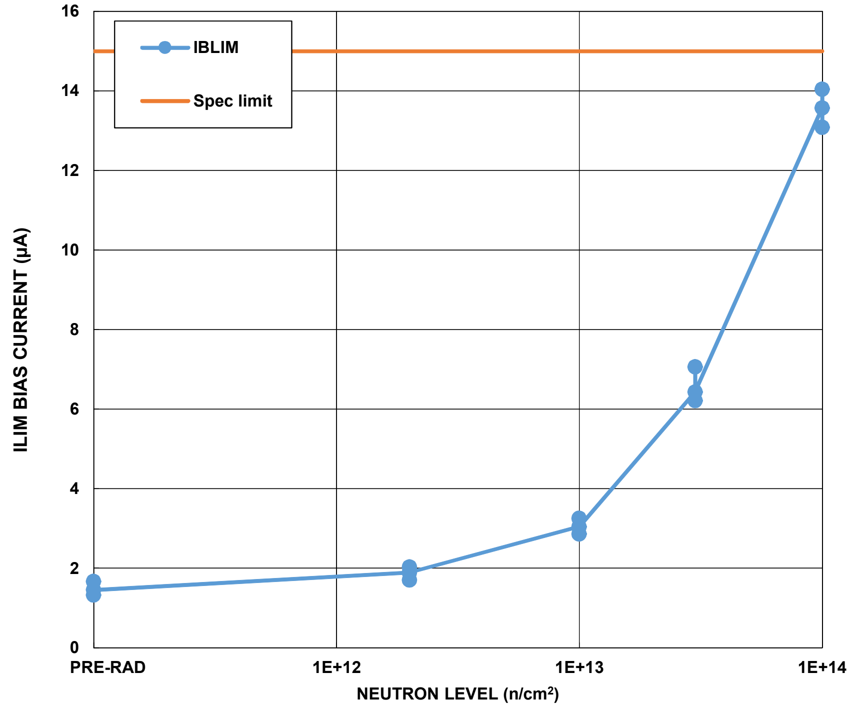

FIGURE 18. HS-1825ARH current limit bias current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 15µA maximum.

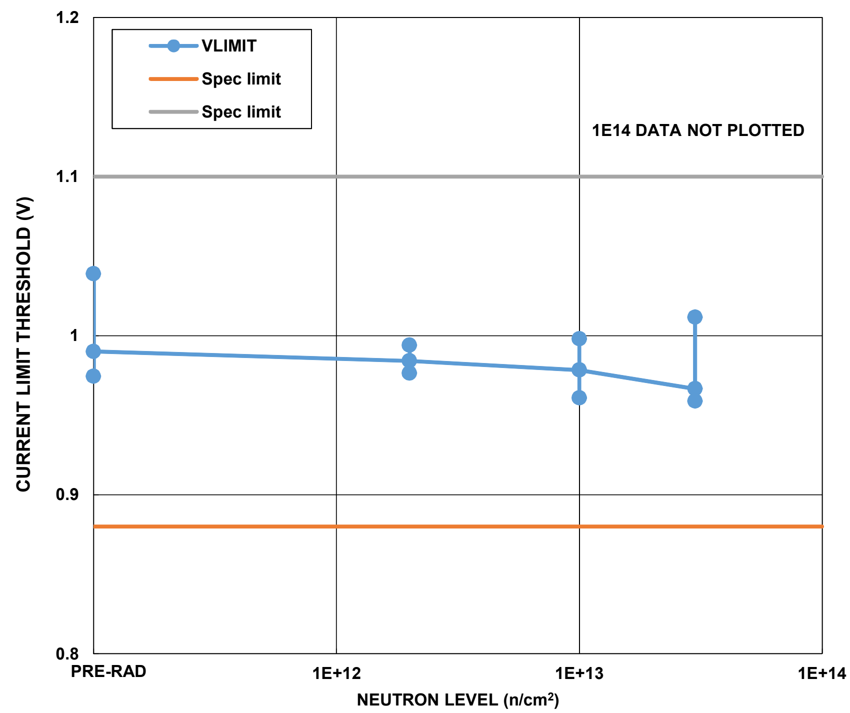

FIGURE 19. HS-1825ARH current limit threshold as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The $1x10^{14}n/cm^2$ data was an ATE overrange and is not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 0.88V to 1.1V.

Variables Data Plots (Continued)

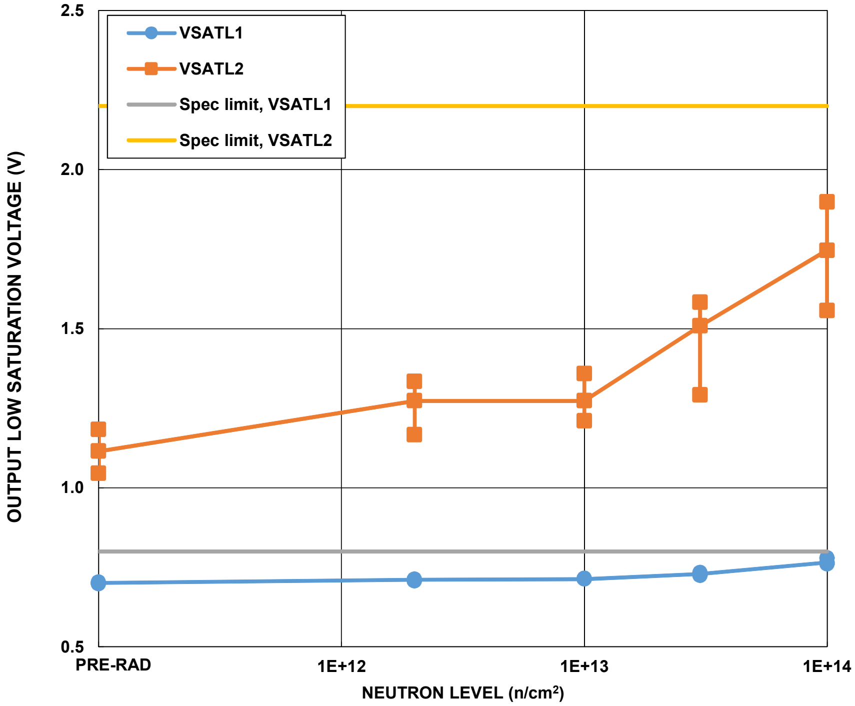

FIGURE 20. HS-1825ARH output LOW saturation voltage, 20mA (V_{SATL1}) and 200mA (V_{SATL2}), as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 0.8V maximum (20mA) and 2.2V maximum (200mA).

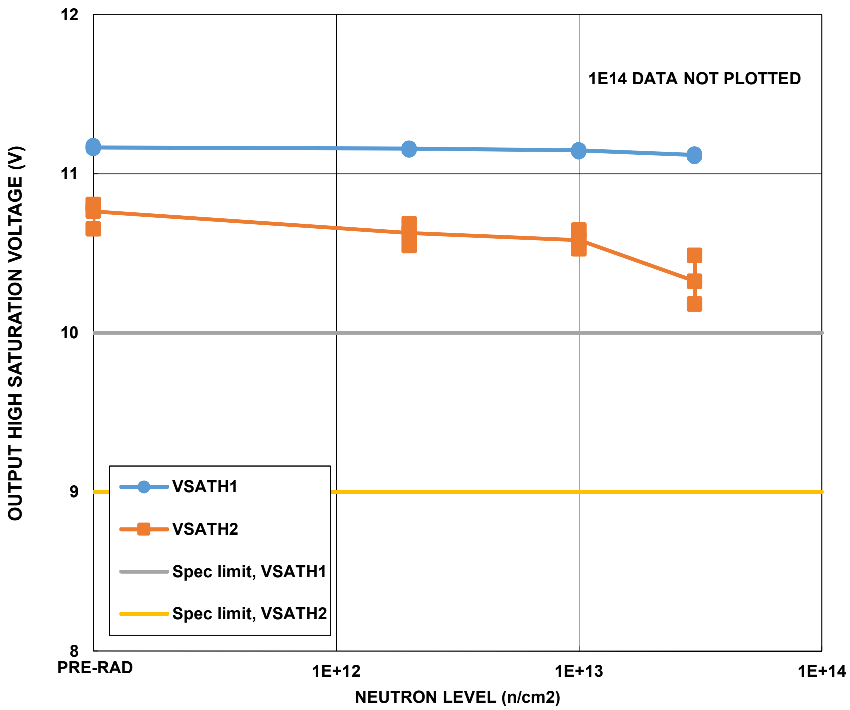

FIGURE 21. HS-1825ARH output HIGH saturation voltage, 20mA (V_{SATH1}) and 200mA (V_{SATH2}), as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The $1x10^{14}n/cm^2$ data points were ATE overranges and are not plotted. The sample size for each cell was 5. The post-total dose irradiation SMD limits are 10V minimum (20mA) and 9V minimum (200mA).

Variables Data Plots (Continued)

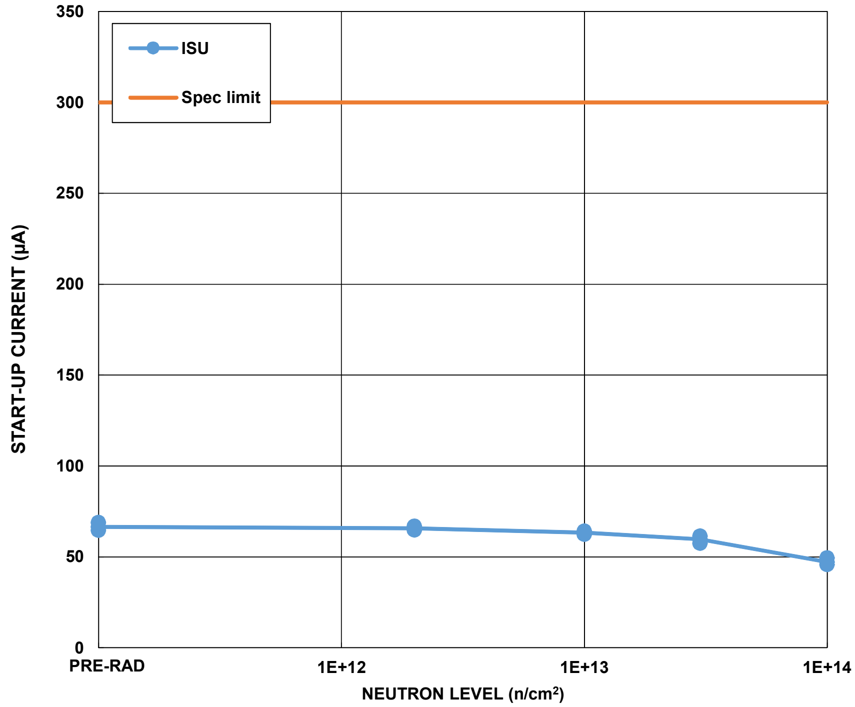

FIGURE 22. HS-1825ARH start-up current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}$ n/cm^2, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 300µA maximum.

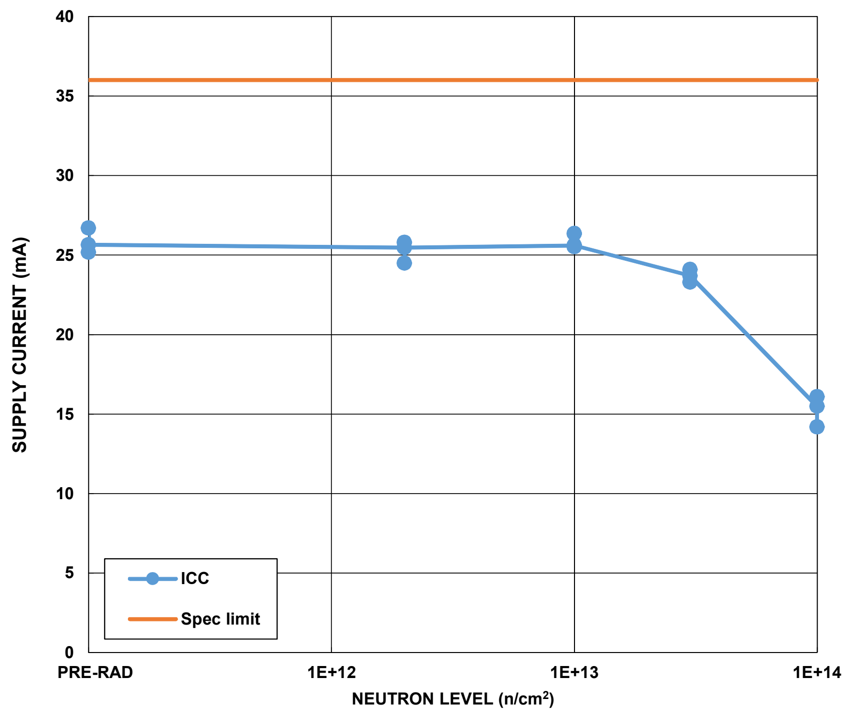

FIGURE 23. HS-1825ARH supply current as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1 x 10^{14}n/cm^2$. The plot shows the population median and minimum and maximum error bars at each downpoint. The sample size for each cell was 5. The post-total dose irradiation SMD limit is 36mA maximum.

Conclusion

This report summarizes results of the 1MeV equivalent neutron testing of the HS-1825ARH Pulse Width Modulator (PWM). 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 test was carried out as part of a collaborative project with Boeing (El Segundo, CA), whose support is gratefully acknowledged.

The samples met all specifications (Bin 1) after $2x10^{11}n/cm^2$ and $1x10^{13}n/cm^2$. The samples showed parametric degradation after $3x10^{13}n/cm^2$ and were nonfunctional after the $1x10^{14}n/cm^2$ irradiation.

Appendices

Reported Parameters

Reported parameters are shown in Table 3. The limits are taken from the applicable SMD and are provided for guidance only as the part is not designed or guaranteed for the neutron environment. The plots show the population median and minimum and maximum error bars at each downpoint.

TABLE 3. REPORTED PARAMETERS

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNITS	NOTES
1	Reference Output Voltage	5	5.2	V	
2	Reference Line Regulation	-20	20	mV	
3	Reference Load Regulation	-50	50	mV	
4	Reference Output SC Current	20	-	mA	
5	Oscillator Initial Accuracy	300	425	kHz	
6	Clock Output Voltage	3.75	-	V	HIGH
	Clock Output Voltage	-	0.2	V	LOW
7	EA Input Offset Voltage	-10	10	mV	
8	EA Input Bias Current	-1	1	µA	
9	EA Input Offset Current	-4	4	µA	
10	EA Open Loop Gain	60	-	dB	
11	EA Common-Mode Rejection Ratio	65	-	dB	
12	EA Power Supply Rejection Ratio	80	-	dB	
13	EA Output Current	-0.5	-	mA	Sourcing
	EA output current	1	-	mA	Sinking
14	EA Output Voltage	4	-	V	HIGH
	EA Output Voltage	-	1	V	LOW
15	PWM Ramp Bias Current	-8	-	µA	
16	PWM Maximum Duty Cycle	40	-	%	
17	Soft-Start Current	8	25	µA	Charging
	Soft-Start Current	100	500	µA	Discharging
18	Current Limit Bias Current	-	15	µA	
19	Current Limit Threshold	0.88	1.1	V	
20	Output Saturation Voltage	-	0.8	V	LOW, 20mA
	Output Saturation Voltage	-	2.2	V	LOW, 200mA

TABLE 3. REPORTED PARAMETERS (Continued)

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNITS	NOTES
21	Output Saturation Voltage	10	-	V	HIGH, 20mA
	Output Saturation Voltage	9	-	V	HIGH, 200mA
22	Start-Up Current	-	300	µA	
23	Supply Current	-	36	mA	

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