HS-4424DRH

Neutron Testing

TR034
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Introduction

This report summarizes results of 1MeV equivalent neutron testing of the HS-4424DRH dual power MOSFET driver. 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-4424DRH Datasheet
- DSCC Standard Microcircuit Drawing (SMD) 5962-99560

Part Description

The radiation hardened HS-4424 family are noninverting dual MOSFET drivers designed to convert low voltage control input signals into higher voltage, high current outputs. The HS-4424DRH and HS-4424DEH are fully tested across the 8V to 18V operating range. The inputs of these devices can be directly driven by the HS-1825ARH PWM device or various logic devices. The fast rise times and high current outputs allow close control of high gate capacitance power MOSFETs in high frequency applications. The high current outputs minimize power losses in MOSFETs by rapidly charging and discharging the gate capacitance. The output stage incorporates a low voltage lockout circuit that puts the outputs into a three-state mode when the supply voltage is below its Undervoltage Lockout (UVLO) threshold voltage. The parts differ in Undervoltage Lockout (UVLO) levels, see Table 1 for UVLO options. Table 2 shows the part's pinout.

Fabricate using Intersil's dielectrically isolated Radiation Hardened Silicon Gate (RSG) BiCMOS process, these devices are immune to single event latch-up and provide highly reliable performance in harsh radiation environments.

TABLE 1. HS4424 UNDERVOLTAGE LOCKOUT THRESHOLD (UVLO) THRESHOLD VOLTAGES

PART NUMBER	UVLO (V)
HS-4424RH, HS-4424EH	<10
HS-4424BRH, HS-4424BEH	<7.5
HS-4424DRH, HS-4424DEH	<8

TABLE 2. IS75051SRH PIN ASSIGNMENTS

TERMINAL NUMBER	TERMINAL SYMBOL	TERMINAL NUMBER	TERMINAL SYMBOL
1	NC	9	NC

TABLE 2. IS75051SRH PIN ASSIGNMENTS

TERMINAL NUMBER	TERMINAL SYMBOL	TERMINAL NUMBER	TERMINAL SYMBOL
2	IN A	10	OUT A
3	NC	11	OUT A
4	GND A	12	VCC
5	GND B	13	VCC
6	NC	14	OUT B
7	IN B	15	OUT B
8	NC	16	NC

The HS-4424DRH is specified for a Total Ionizing Dose (TID) tolerance of 300krad(Si) at high (50-300rad(Si)/s) dose rate and at 50krad(Si) at low (< 0.01rad(Si)/s) dose rate. The HS-4424DRH is acceptance tested on a wafer-by-wafer basis at high dose rate to 300krad(Si). The HS-4424DEH variant is acceptance tested on a wafer-by-wafer basis at low dose rate to 50krad(Si) and at high dose rate to 300krad(Si).

The HS-4424DRH is also Single-Event Effects (SEE) tolerant to a Linear Energy Transfer (LET) value of $86.4MeV \cdot cm^2/mg$. Single-Event Transients (SET) have evolved into a major issue in power management parts driving voltage-sensitive loads, and the part provides superior performance in this environment.

Specifications for Radiation Hardened QML devices are controlled by the Defense Logistics Agency (DLA) in Columbus, OH. The SMD is the controlling document.

Test Description

Irradiation Facilities

Neutron irradiation was performed at the White Sands Missile Range fast burst reactor. Parts were tested in an unbiased configuration with all leads shorted together in 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 'cooldown' time before being shipped back to Intersil (Palm Bay, FL) for electrical testing.

Test Fixturing

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

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.

Experimental Matrix

Testing proceeded in general accordance with the guidelines of MIL-STD-883 Test Method 1017. 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 $1 \times 10^{14}n/cm^2$. Five control units were used.

HS-4424DRH/PROTO samples were drawn from fabrication lot G3D2TB. Samples were packaged in the standard hermetic 16 Ld ceramic flatpack production package, code K16.E and were screened to the SMD limits over temperature before irradiation.

Results

Neutron testing of the HS-4424DRH 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 3. HS-4424DRH ATTRIBUTES DATA

PART	SERIAL	SAMPLE SIZE	FLUENCE, (n/cm^2)	PASS (Note 1)	FAIL	NOTES
HS-4424DRH	1-5	5	2×10^{12}	5	0	All passed
HS-4424DRH	6-10	5	1×10^{13}	5	0	All passed
HS-4424DRH	11-15	5	3×10^{13}	5	0	All passed, IIL increased
HS-4424DRH	16-20	5	1×10^{14}	0	5	All failed parametrically, IIL out of specification but all samples were functional

NOTE:

1. ‘Pass’ indicates a sample that passes all SMD post-total dose limits.

Variables Data

The plots in Figures 1 through 13 show data plots for key parameters before and after irradiation to each level. The reported parameters and their datasheet limits are shown again in Table 4 on page 10. The plots show the population median of each parameter as a function of neutron irradiation as well as population maximum/minimum range 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 taken from the SMD; it should be carefully noted that these limits are provided for *guidance only* as the HS-4424DRH 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 some limited neutron testing for customer guidance.

Variables Data Plots

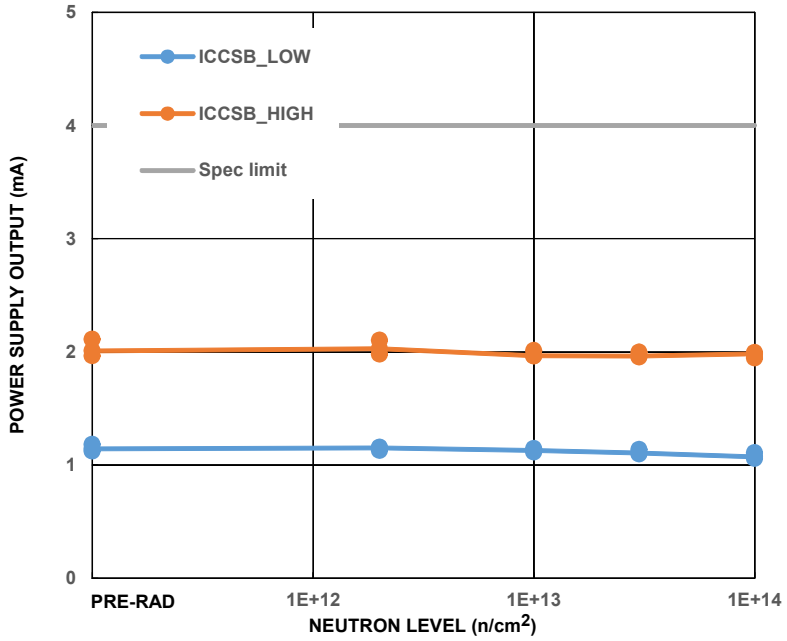

FIGURE 1. HS-4424DRH power supply current, outputs LOW and HIGH, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The SMD post-total dose limit is 4mA maximum.

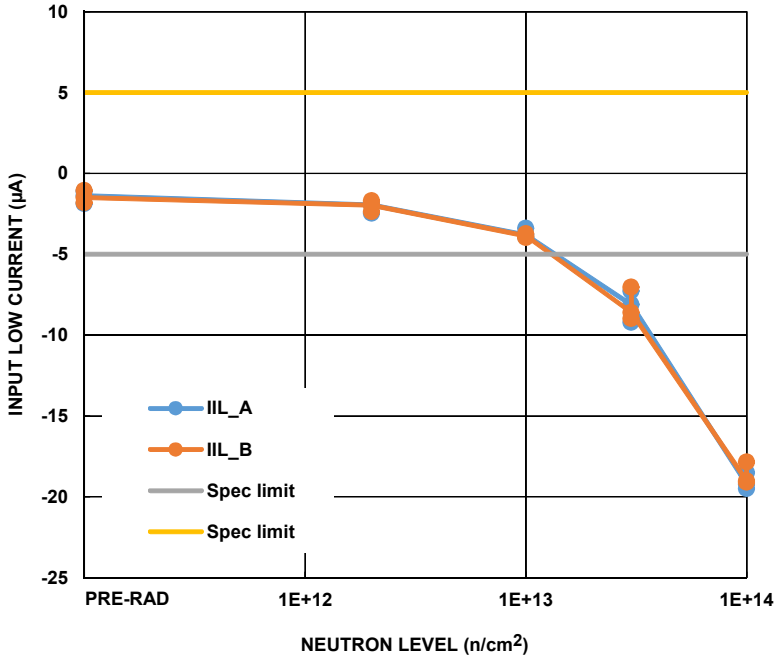

FIGURE 2. HS-4424DRH input LOW current, Channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The SMD post-total dose limits are -5µA to 5µA.

Variables Data Plots

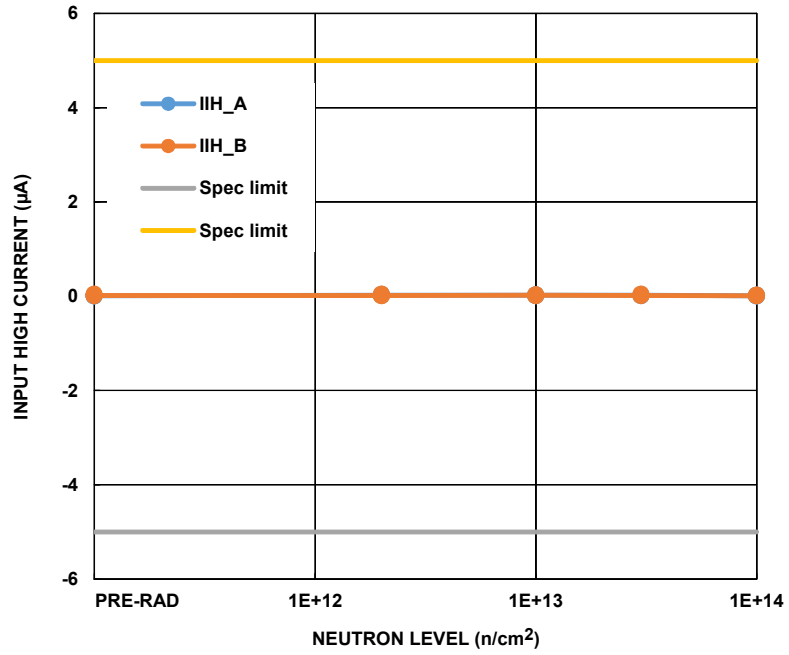

FIGURE 3. HS-4424DRH input HIGH current, Channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limits are -5µA to 5µA.

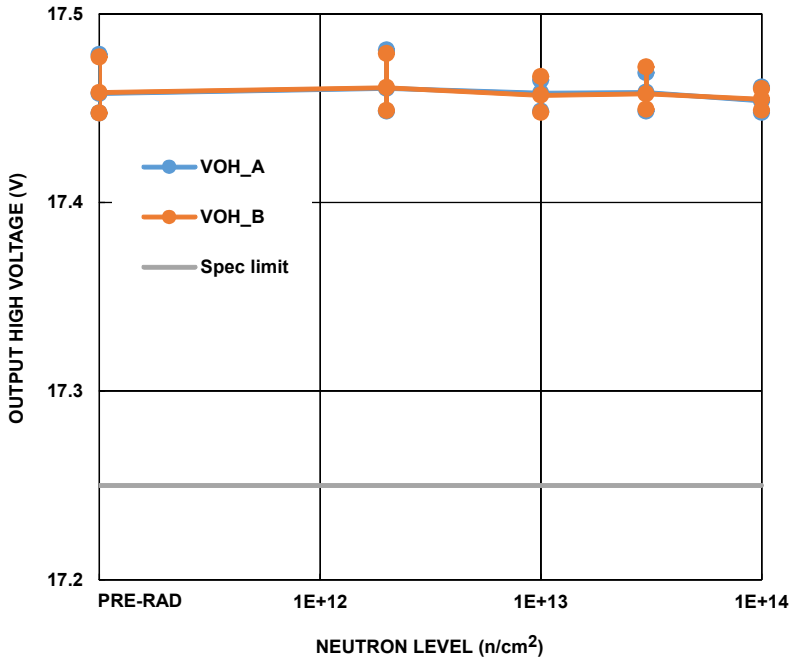

FIGURE 4. HS-4424DRH output HIGH voltage, Channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limit is 17.25V minimum.

Variables Data Plots

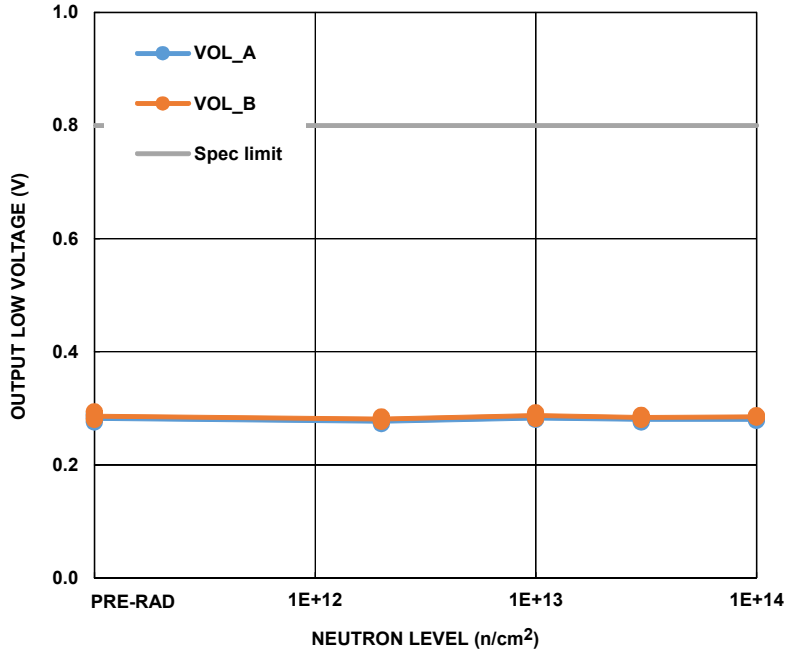

FIGURE 5. HS-4424DRH output LOW voltage, Channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limit is 0.8V maximum.

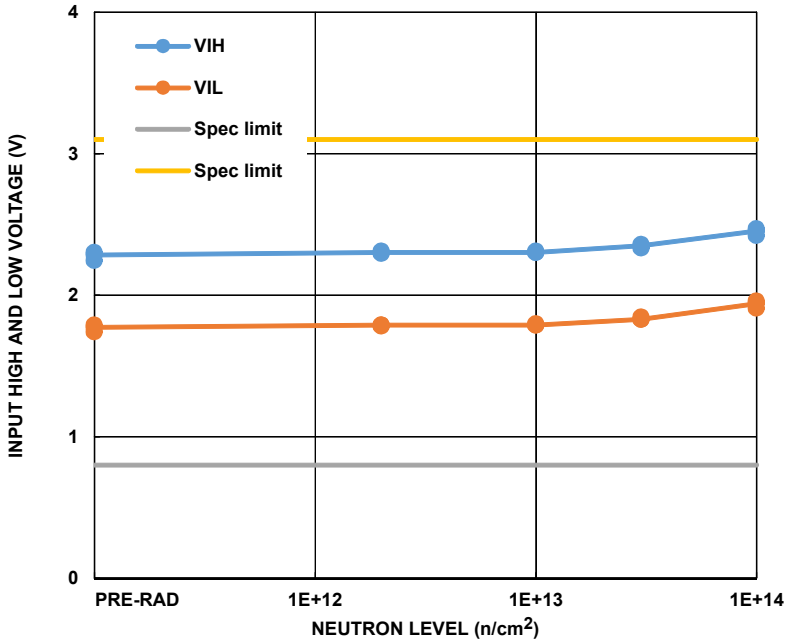

FIGURE 6. HS-4424DRH input HIGH and LOW threshold voltage as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limits are 3.1V maximum (V_{IH}) and 0.8V minimum (V_{IL}).

Variables Data Plots

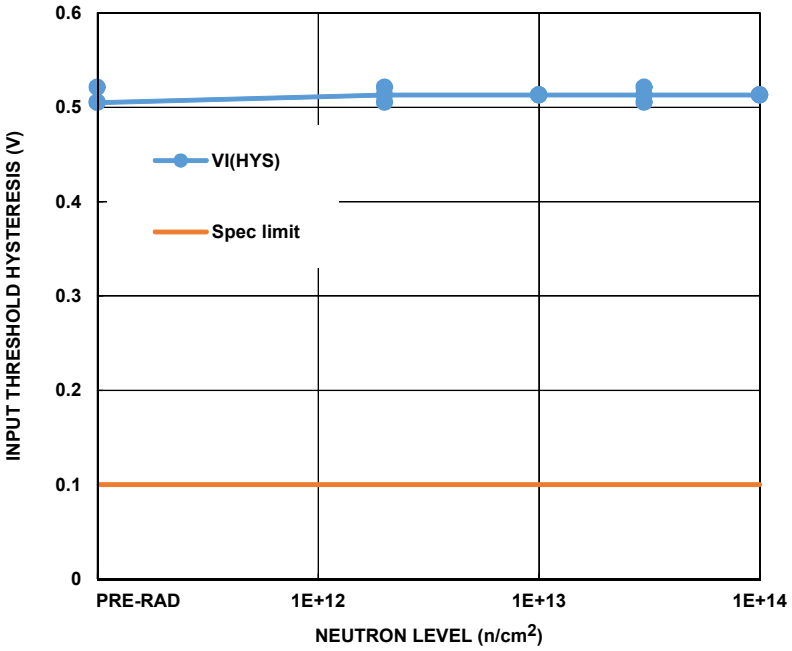

FIGURE 7. HS-4424DRH input threshold voltage hysteresis as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limit is 0.1V minimum.

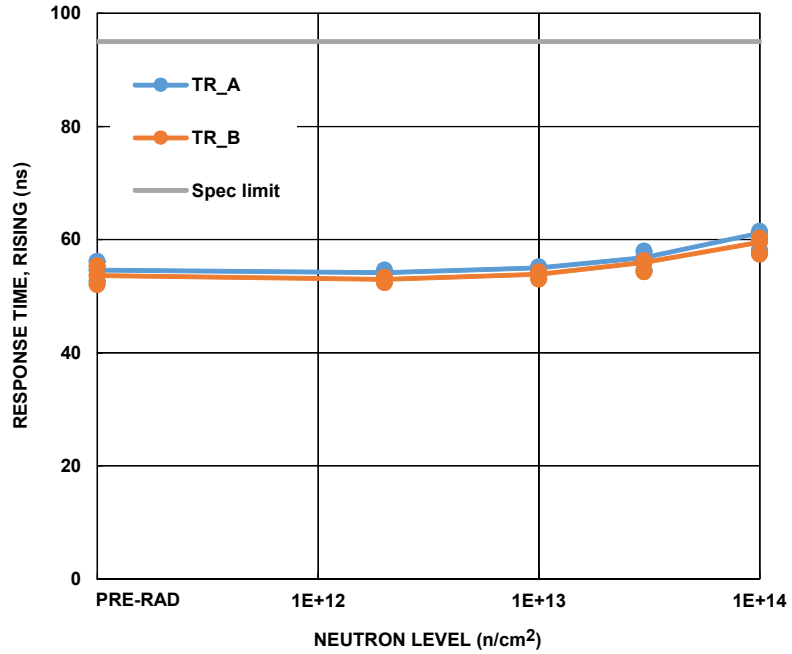

FIGURE 8. HS-4424DRH rising response time, Channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limit is 95ns maximum.

Variables Data Plots

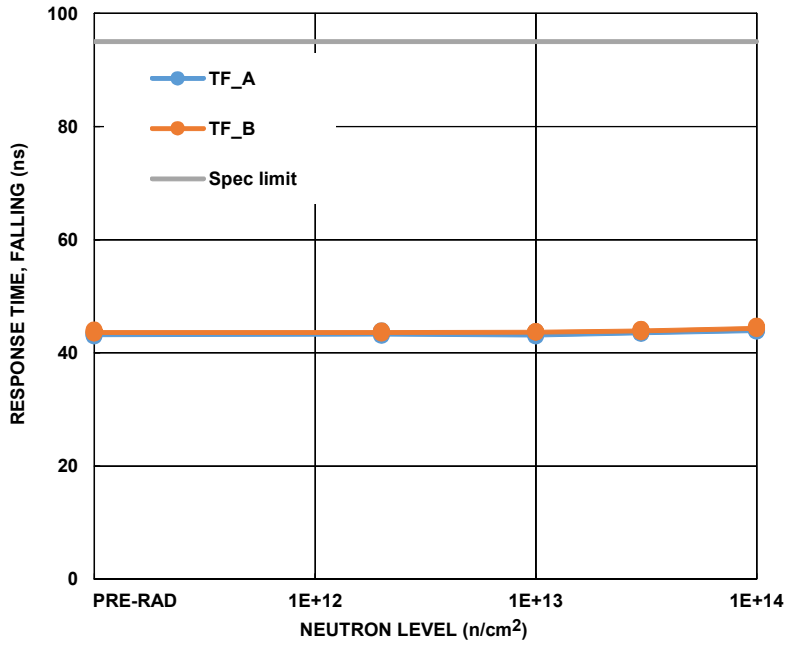

FIGURE 9. HS-4424DRH falling response time, Channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limit is 95ns maximum.

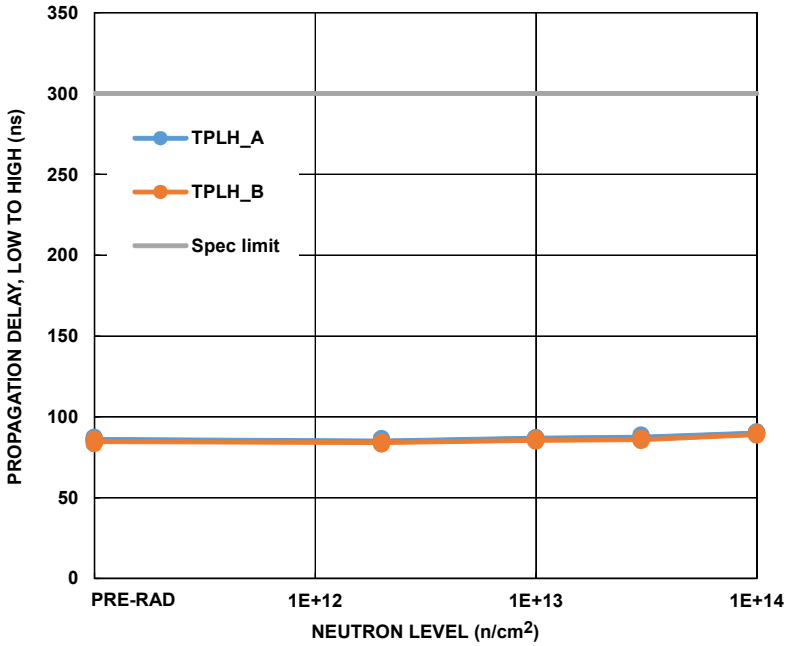

FIGURE 10. HS-4424DRH propagation delay, LOW to HIGH, Channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limit is 300ns maximum.

Variables Data Plots

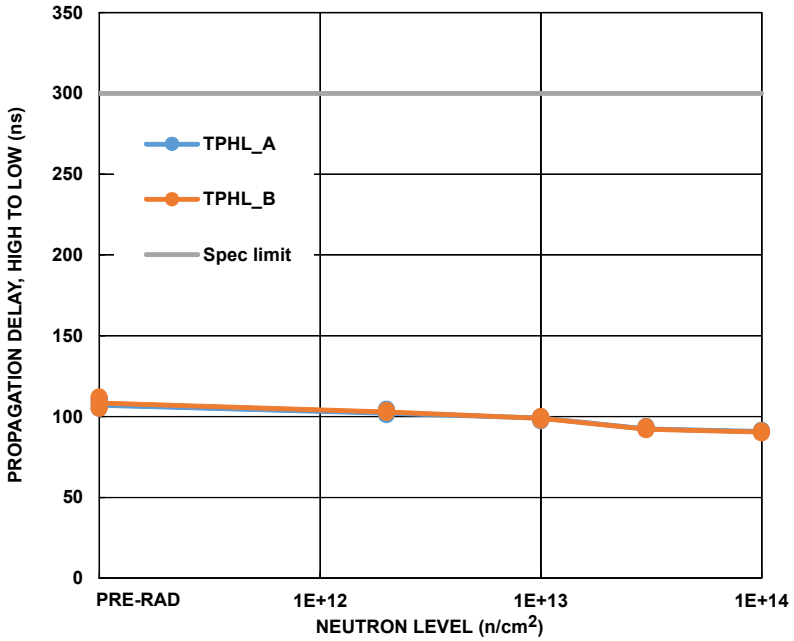

FIGURE 11. HS-4424DRH propagation delay, HIGH to LOW, Channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limit is 300ns maximum.

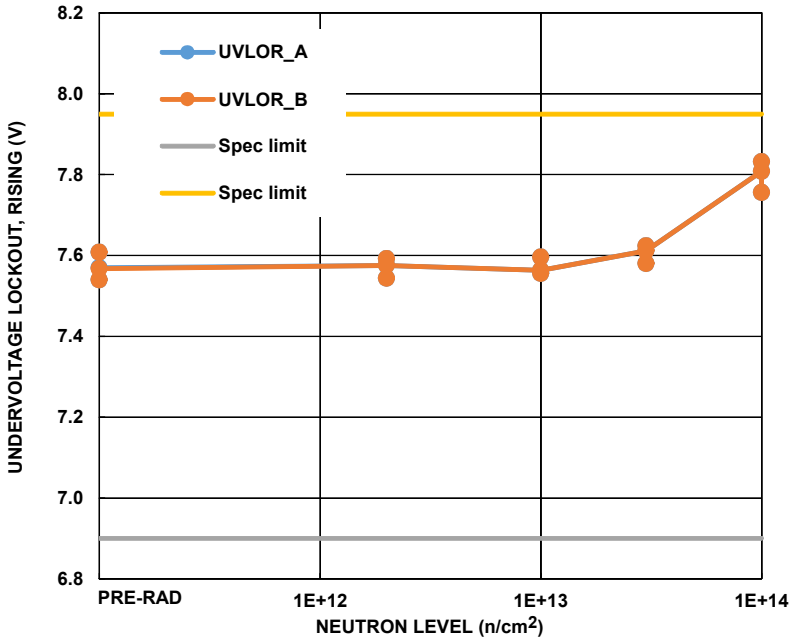

FIGURE 12. HS-4424DRH rising undervoltage lockout level, Channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limits are 6.9V to 7.95V.

Variables Data Plots

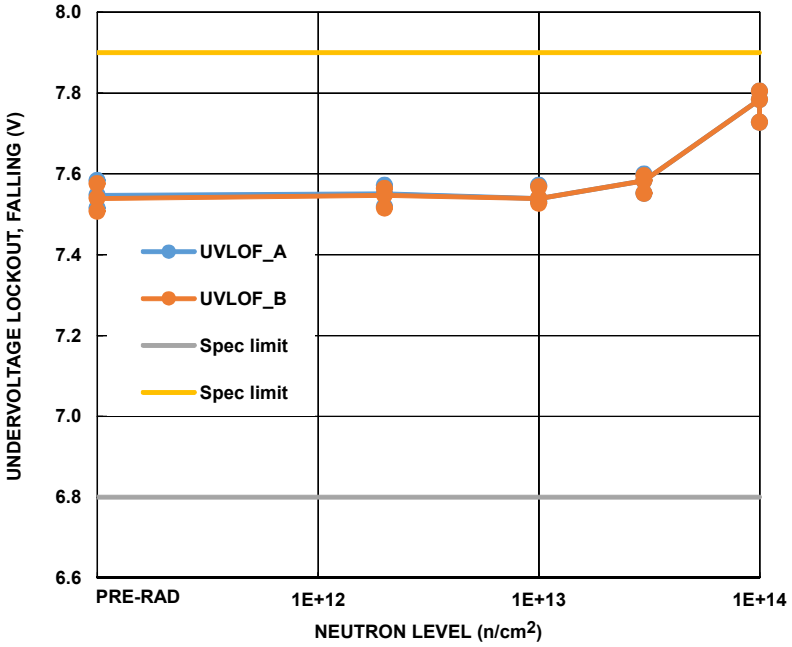

FIGURE 13. HS-4424DRH falling undervoltage lockout level, channels A and B, as a function of 1MeV equivalent neutron irradiation at $2x10^{12}n/cm^2$, $1x10^{13}n/cm^2$, $3x10^{13}n/cm^2$ and $1x10^{14}n/cm^2$. The plot shows the population median and minimum and maximum range bars at each downpoint. Sample size for each cell was 5. The post-total dose SMD limits are 6.8V to 7.9V.

Conclusion

This report summarizes results of 1MeV equivalent neutron testing of the HS-4424DRH power MOSFET driver. 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 $2x10^{11}n/cm^2$ and $1x10^{13}n/cm^2$. After $3x10^{13}n/cm^2$ all samples passed but the average input LOW current (Figure 2 on page 3) was -8µA, near the -10µA limit. After $1x10^{14}n/cm^2$ all samples failed input LOW current parametrically, with an average of 18µA; all samples were however still functional.

Appendices

Reported Parameters

Reported parameters are shown below. 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. A number of parameters are plotted in the same figure (see for example Figure 6 on page 5, which plots the neutron response of both the input HIGH and input LOW currents) in order to save space. The plots show the population median and minimum and maximum range bars at each downpoint.

TABLE 4. REPORTED PARAMETERS

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNITS	NOTES
1	Power supply current	-	4	mA	Outputs HIGH and LOW
2	Input LOW current	-5	5	µA	Channels A and B
3	Input HIGH current	-5	5	µA	Channels A and B
4	Output HIGH voltage	17.25	-	V	Channels A and B
5	Output LOW voltage	-	0.8	V	Channels A and B
6	Input HIGH threshold voltage	-	3.1	V	
	Input LOW threshold voltage	0.8	-	V	
7	Input threshold voltage hysteresis	0.1	-	V	
8	Rising response time	-	95	ns	Channels A and B
9	Falling response time	-	95	ns	Channels A and B
10	Propagation delay, LOW to HIGH	-	300	ns	Channels A and B
11	Propagation delay, HIGH to LOW	-	300	ns	Channels A and B
12	Rising UVLO level	6.9	7.95	V	
13	Falling UVLO level	6.8	7.9	V	

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