HS-4423EH

Total Dose Testing

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Introduction

This document reports the results of low and high dose rate total dose testing of the HS-4423EH inverting power MOSFET driver. The tests were conducted to provide an assessment of the total dose hardness of the part. Parts were irradiated under bias and with all pins grounded at low dose rate and under bias at high dose rate. The samples were also taken out to an overtest and subsequent anneal sequence as described in MIL-STD-883 Test Method 1019. Anneals were performed under bias at an ambient temperature of +100°C for 168 hours. These tests were run as part of production acceptance testing of the part.

The HS-4423 and HS-4424 are available in several variants differing in inverting/noninverting operation, low voltage lockout specification and total ionizing dose acceptance testing. We have summarized the variants in Table 1. The “RH” and “EH” devices are of the same design and silicon.

TABLE 1. HS-442x VARIANTS

PART NUMBER (Note 4)	FUNCTION	LVLO (V) (Note 1)	ACCEPTANCE TESTING
HS-4423RH (Note 2)	Inverting	10	High dose rate only
HS-4423BRH (Note 2)	Inverting	7.5	High dose rate only
HS-4424RH (Note 2)	Noninverting	10	High dose rate only
HS-4424BRH (Note 2)	Noninverting	7.5	High dose rate only
HS-4423EH (Note 3)	Inverting	10	Low and high dose rate
HS-4423BEH (Note 3)	Inverting	7.5	Low and high dose rate
HS-4424EH (Note 3)	Noninverting	10	Low and high dose rate
HS-4424BEH (Note 3)	Noninverting	7.5	Low and high dose rate

NOTES:

1. 'LVLO' indicates the low voltage lockout parameter.
2. 'RH' parts are acceptance tested on a wafer-by-wafer basis through biased high dose rate irradiation to the SMD high dose rate level of 300rad(Si).
3. 'EH' parts are acceptance tested on a wafer-by-wafer basis through biased and grounded low dose rate irradiation to the SMD low dose rate level of 50krad(Si) and through biased high dose rate irradiation to the SMD high dose rate level of 300rad(Si).
4. The high dose rate is 50-300rad(Si)/s and the low dose rate is 0.01rad(Si)/s.

The HS-4423EH and HS-4423BEH differ only in the LVLO level, and the present HS-4423EH data applies directly to the HS-4423BEH variant.

Reference Documentation

- MIL-STD-883 test method 1019
- HS-4423 datasheet
- HS-4424 datasheet
- Standard Microcircuit Drawing (SMD) 5962-99511

Part Description

The radiation hardened HS-4423RH, HS-4423EH, HS-4423BRH and HS-4423BEH are inverting, dual, monolithic high-speed MOSFET drivers designed to convert TTL level signals into high current outputs at voltages up to 18V. The inputs of these devices are TTL compatible and can be directly driven by the Intersil HS-1825ARH PWM controller or by Intersil ACS/ACTS and HCS/HCTS type logic devices. The fast rise times and high current outputs allow effective 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 drops below 10V for the HS-4423RH, HS-4423EH and 7.5V for the HS-4423BRH, HS-4423BEH.

Constructed using the Intersil 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. Specifications for QML devices are controlled by the Defense Logistics Agency Land and Maritime (DLA). Detailed electrical specifications for these devices are contained in SMD 5962-99511.

The HS-4423EH and HS-4423BEH are available in a 16 Ld hermetic ceramic flatpack and in die form. The part offers guaranteed performance over the full -55°C to +125°C military temperature range.

Key Pre- and Post-Radiation Specifications

- Peak output current . . . . . 2A minimum
- Rise and fall times (CL= 4300pF) . . . . . 75ns maximum
- Low voltage lockout (HS-4423) . . . . . 10V maximum
- Low voltage lockout (HS-4423B) . . . . . 7.5V maximum
- Supply voltage range . . . . . 12V to 18V
- Propagation delay . . . . . 250ns maximum
- Power consumption . . . . . 40mW, inputs HIGH
- Power consumption . . . . . 20mW, inputs LOW
- Input capacitance . . . . . 3.2pF typical

Test Description

Irradiation Facilities

High dose rate testing was performed at approximately 55rad(Si)/s using a Gammacell 220 ^{60}Co irradiator located in the Palm Bay, Florida Intersil facility. Low dose rate testing was performed at 0.01rad(Si)/s using the Intersil Palm Bay N40 panoramic ^{60}Co irradiator. The post-high dose rate anneal operation was performed in a small temperature chamber.

Test Fixturing

Figure 1 shows the configuration used for biased irradiation. The grounded irradiations were performed in the same fixture type with all pins hardwired to ground.

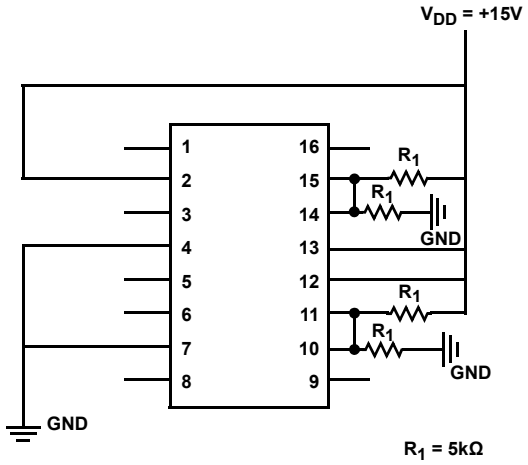

FIGURE 1. BIASED AND UNBIASED (GROUNDED) IRRADIATION BIAS CONFIGURATIONS FOR THE HS-4423EH

Characterization Equipment and Procedures

All electrical testing was performed outside the irradiator using production Automated Test Equipment (ATE) with datalogging at each downpoint. Downpoint electrical testing was performed at room temperature. Three control units were used to insure repeatability.

Experimental Matrix

The experimental matrix consisted of 12 samples irradiated at low dose rate under bias, 12 samples irradiated at low dose rate with all pins grounded and 55 samples irradiated at high dose rate under bias. These tests were run as part of production acceptance testing of the part. The samples of the HS-4423EH were drawn from production lot DAXD6RHS1 and were packaged in a hermetic 16-pin solder-sealed ceramic flatpack package. Samples were processed through the standard burnin cycle before irradiation, as required by MIL-STD-883, and were screened to the ATE limits at room temperature prior to the test.

Downpoints

Downpoints for the low dose rate tests were zero, 10, 30, 50 and 100krad(Si). Downpoints for the high dose rate tests were 0 and 300krad(Si). The low dose rate irradiations were followed by a 168 hour anneal under bias at +100°C.

Results

Attributes Data

Table 2 shows the attributes data for the test.

TABLE 2. HS-4423EH TOTAL DOSE TEST ATTRIBUTES DATA

DOSE RATE (rad(Si)/s)	BIAS	SAMPLE SIZE	DOWNPOINT	BIN 1	REJECTS
0.01	Figure 1	12	0	12	0
			10krad(Si)	12	0
			30krad(Si)	12	0
			50krad(Si)	12	0
			100krad(Si)	0	12
			Anneal	12	0
0.01	Grounded	12	0	12	0
			10krad(Si)	12	0
			30krad(Si)	12	0
			50krad(Si)	12	0
			100krad(Si)	0	12
			Anneal	12	0
55	Figure 1	84	0	84	0
			300krad(Si)	84	0

NOTES:

5. 'Bin 1' indicates a device that passes all pre-irradiation specification limits.
6. The 168-hour anneal was performed at +100°C using the bias configuration shown in Figure 1

Variables Data

The plots in Figures 2 through 12 show data at all downpoints including the post-low dose rate anneal data. The plots show the response to total dose irradiation at low dose rate for the biased and unbiased cases and at high dose rate for the biased case. In addition the plots show the response of the low dose rate samples to a post-irradiation anneal at +100°C for 168 hours. "Discussion and Conclusion" on page 9 will provide individual discussion of the curves.

The low dose rate data showed no failures through 50krad(Si). At the 100krad(Si) level all 12 of the biased and grounded samples failed. These were parametric failures and were for the A channel input LOW current exceeding the ±4µA limits. No further data is available as the ATE testing stopped on first fail. The failed devices were retained in the test and were subjected to the post-irradiation anneal along with the passing parts; interestingly, all samples again met the ±4µA specification limits after anneal.

The high dose rate samples showed no failures after 300krad(Si); no anneal was performed.

No differences in total dose response were noted between biased and grounded irradiation for any parameters. Additionally, no channel-to-channel differences were noted, either in the pre-irradiation data or in the total dose response of the parts.

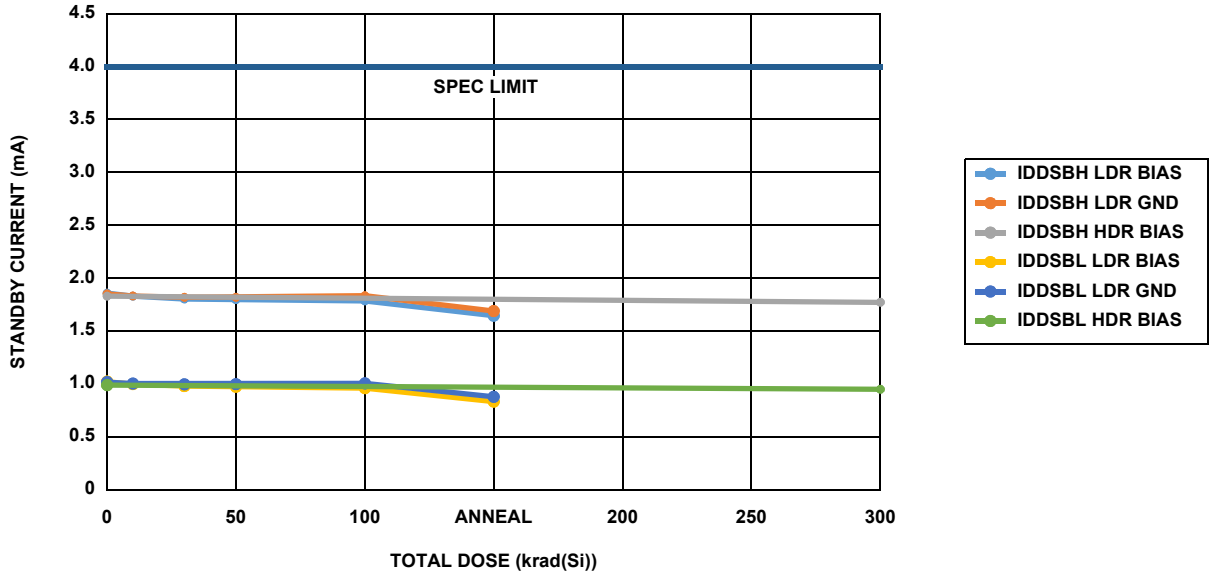

FIGURE 2. HS-4423EH HIGH and LOW standby supply current as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limit is 4mA maximum.

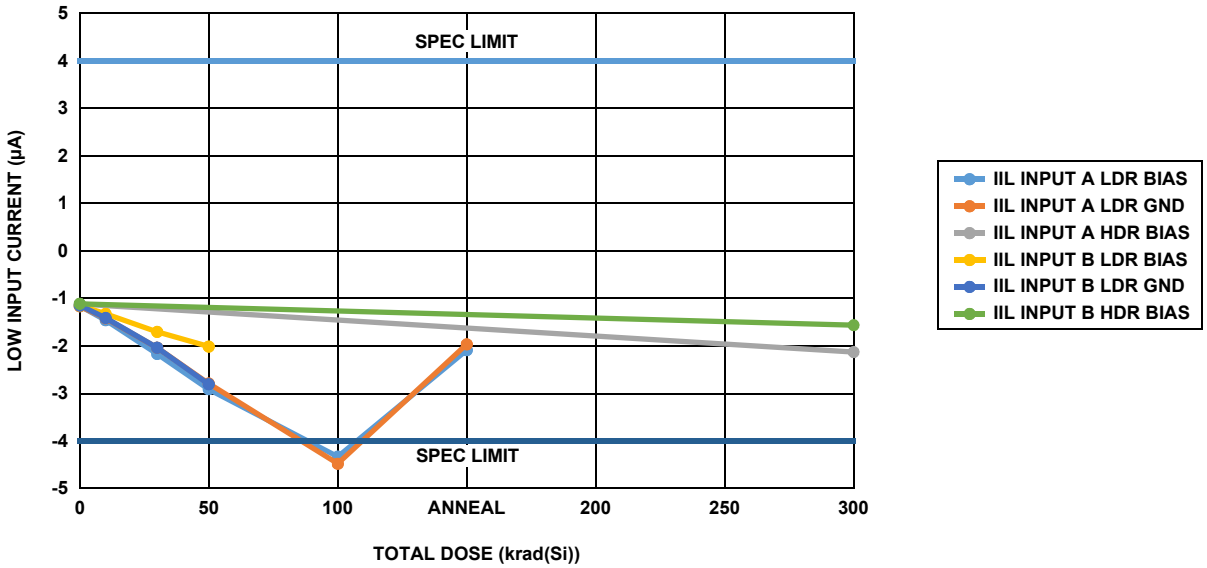

FIGURE 3. HS-4423EH LOW input current as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limits are -4µA to 4µA. The Channel B data for the samples that failed at 100krad(Si) is removed from the population due to the 'stop on first fail' performed by the ATE, see previous discussion.

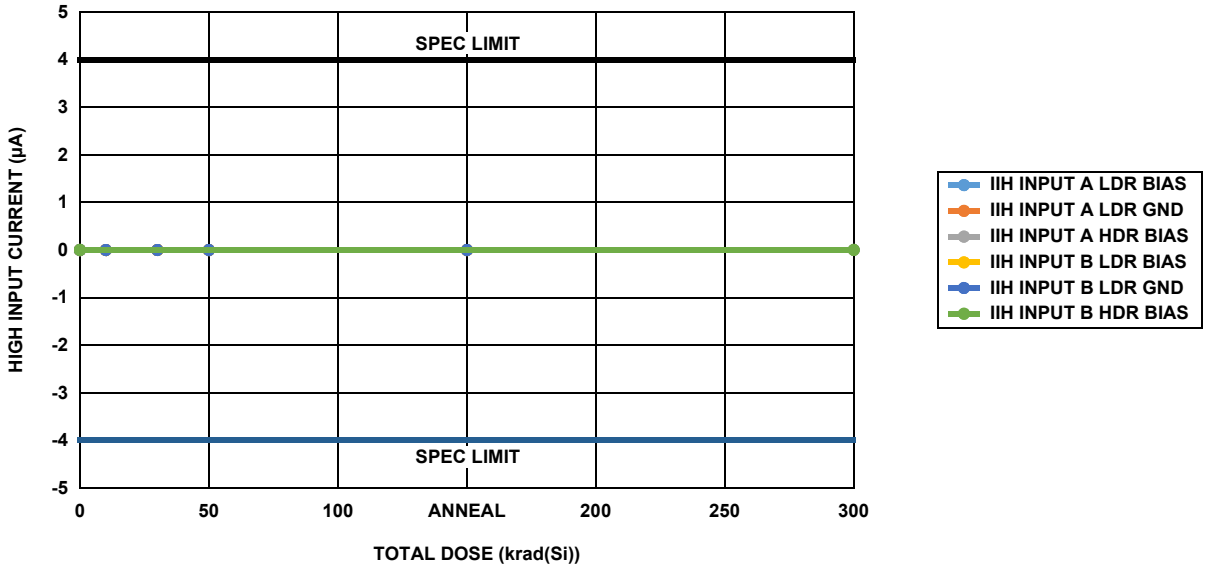

FIGURE 4. HS-4423EH HIGH input current as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limits are -4µA to 4µA.

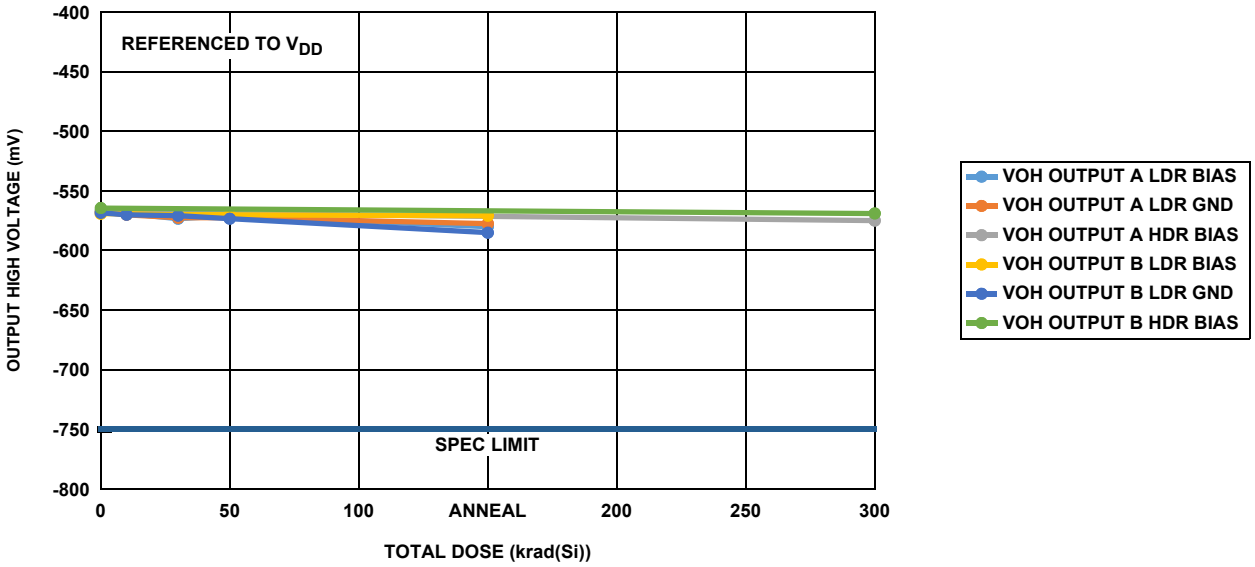

FIGURE 5. HS-4423EH output HIGH voltage, referenced to V_{DD}, as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limit is -750mV minimum.

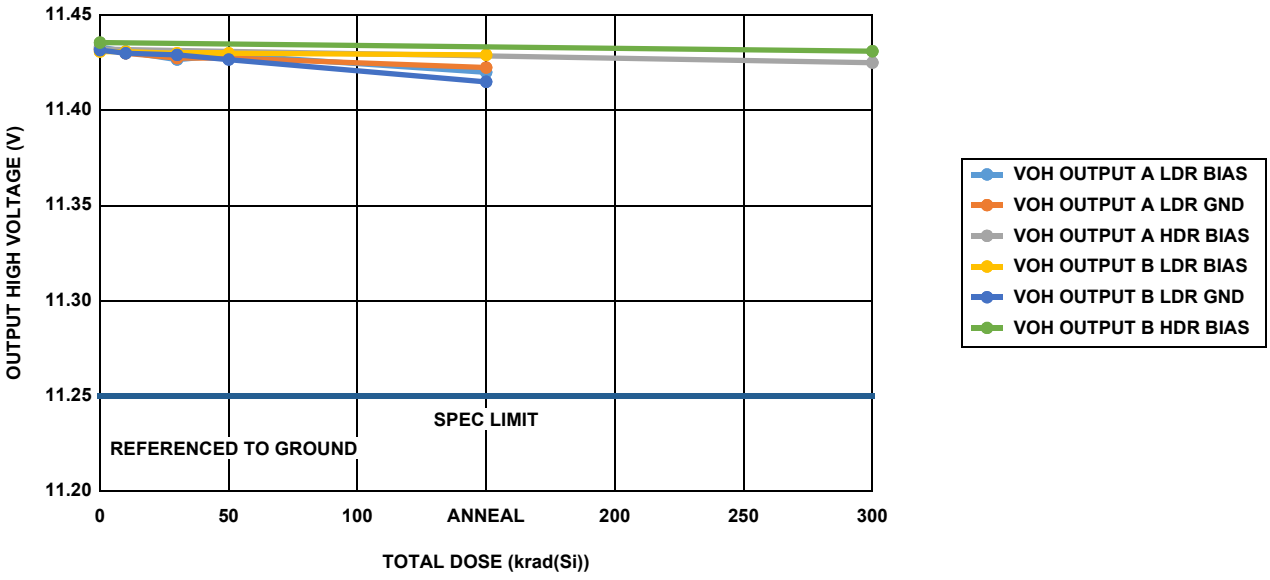

FIGURE 6. HS-4423EH output HIGH voltage, referenced to ground, as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limit is 11.25V minimum.

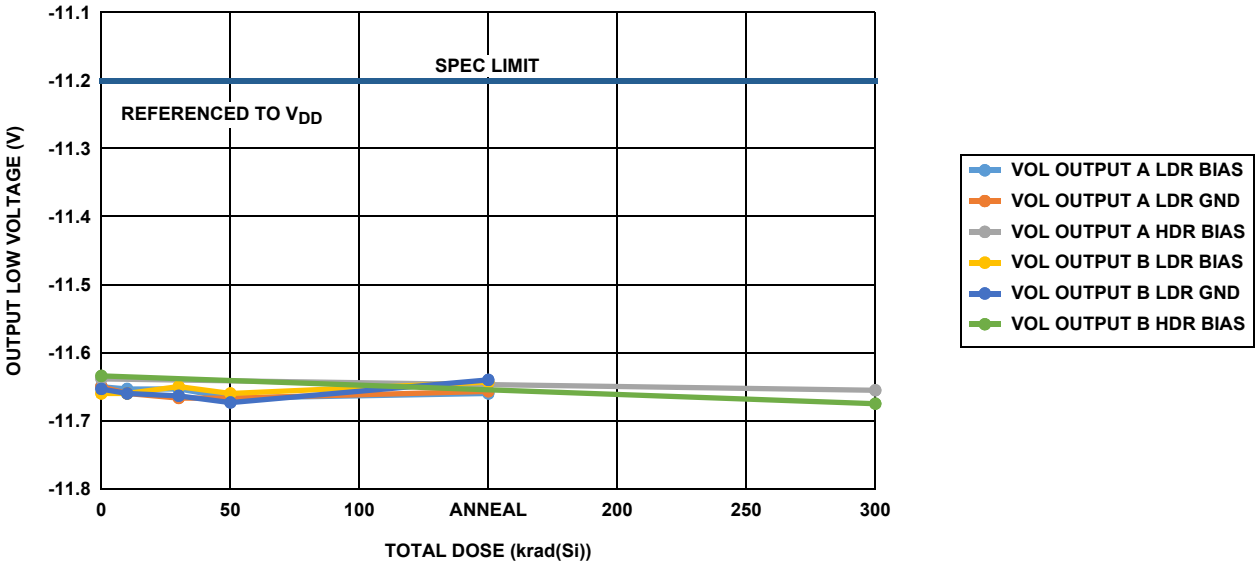

FIGURE 7. HS-4423EH output LOW voltage, referenced to V_{DD}, as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limit is -11.2V maximum.

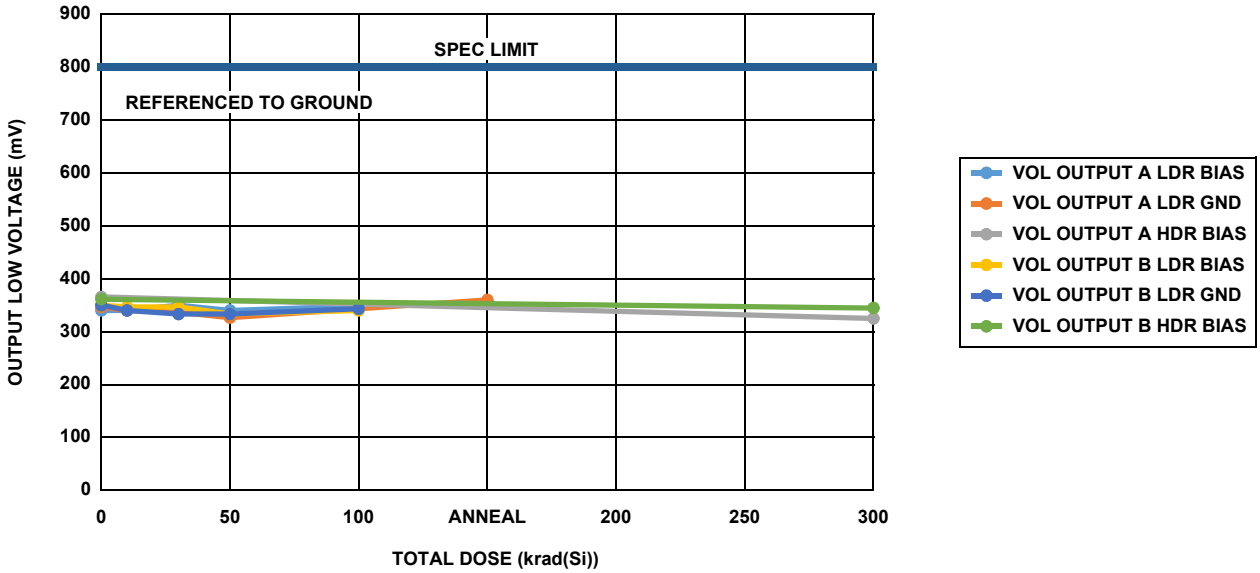

FIGURE 8. HS-4423EH output LOW voltage, referenced to ground, as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limit is 800mV maximum.

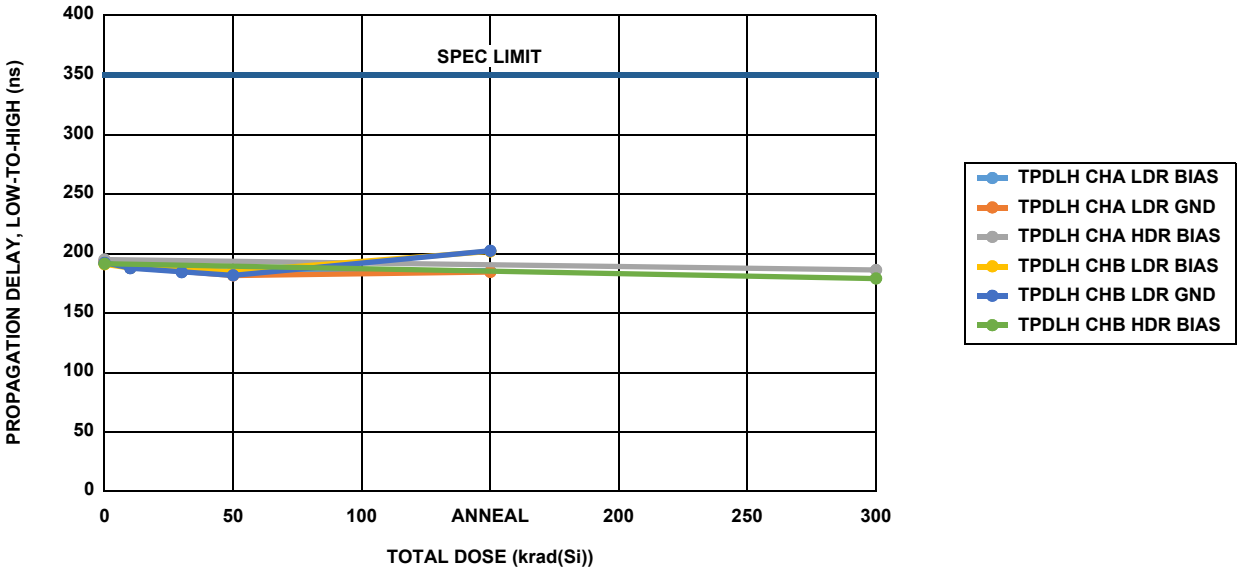

FIGURE 9. HS-4423EH LOW-to-HIGH propagation delay as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limit is 350ns maximum.

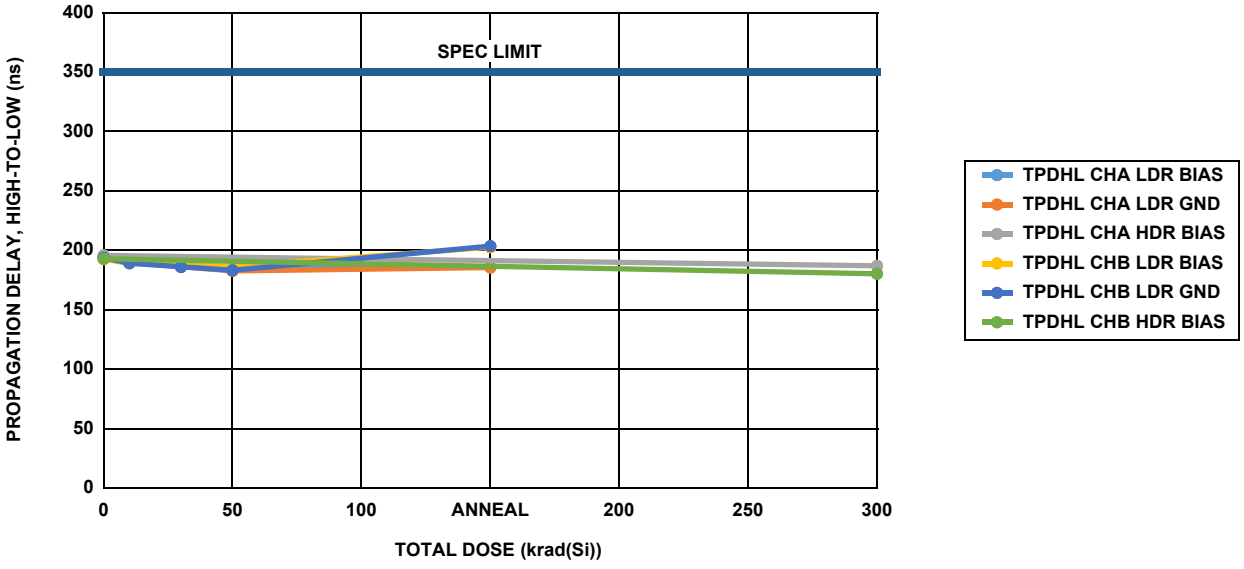

FIGURE 10. HS-4423EH HIGH-to-LOW propagation delay as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limit is 350ns maximum.

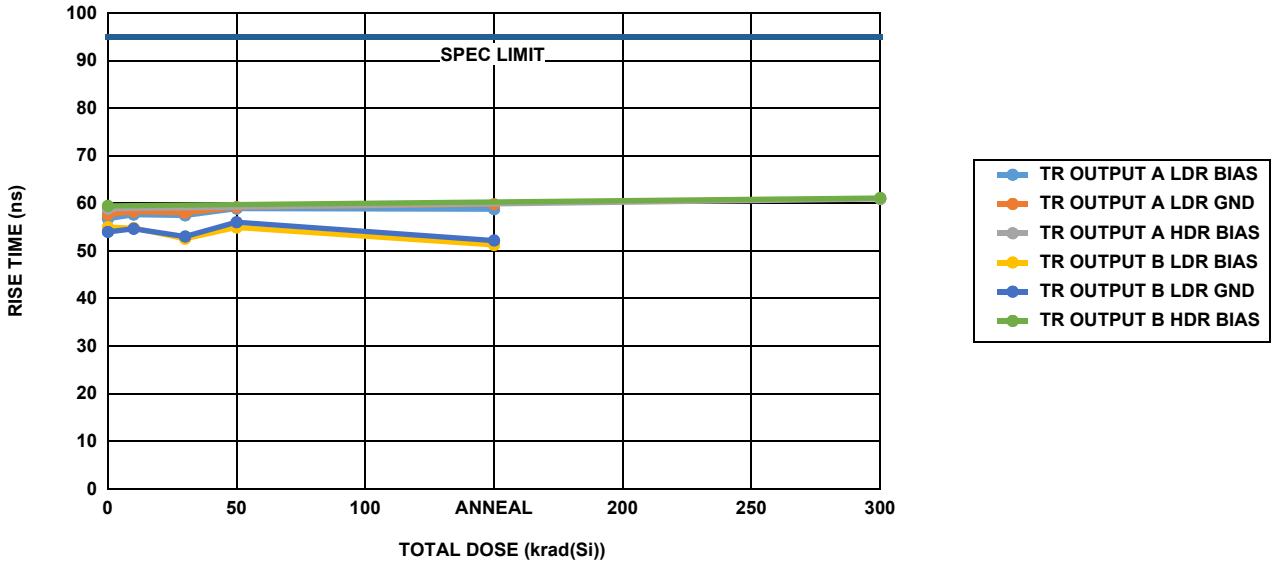

FIGURE 11. HS-4423EH rise time as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limit is 95ns maximum.

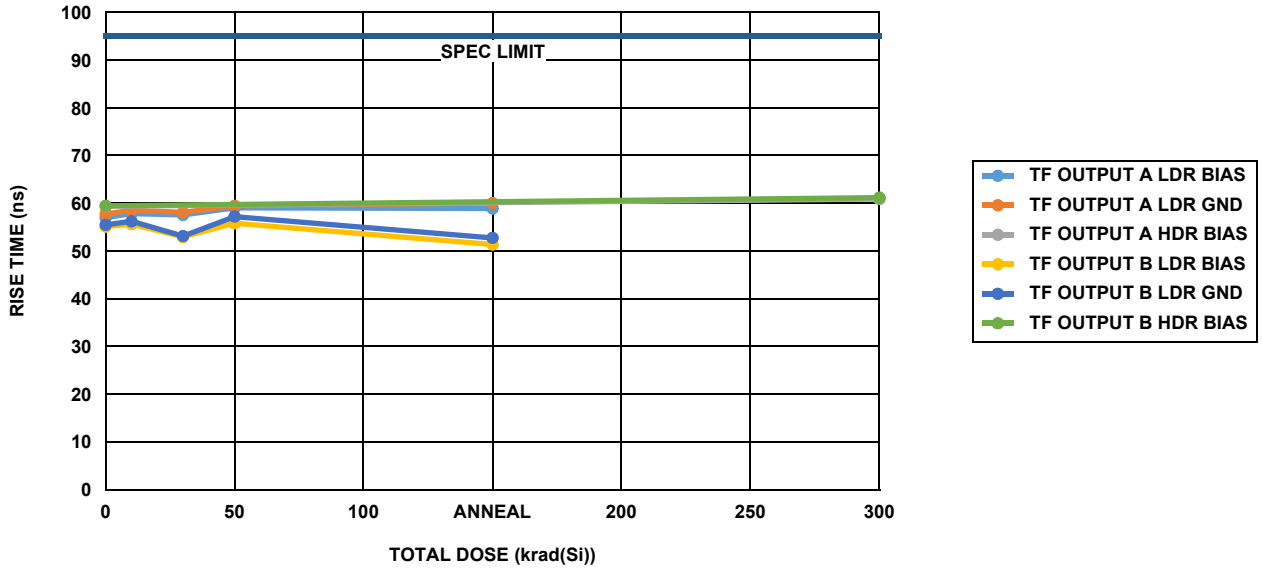

FIGURE 12. HS-4423EH fall time as a function of total dose irradiation at low dose rate for the biased (per Figure 1) and unbiased (all pins grounded) cases and at high dose rate for the biased (Figure 1) case. The dose rate was 0.01rad(Si)/s for low dose rate irradiation and 55rad(Si)/s for high dose rate irradiation. Low dose rate irradiations were followed by a high temperature biased anneal. The sample size for the two low dose rate cells was 12 and the sample size for the high dose rate cell was 84. The post-irradiation specification limit is 95ns maximum.

Discussion and Conclusion

This document reports results of low and high dose rate testing of the HS-4423EH inverting power MOSFET driver. Parts were tested at low dose rate under biased and unbiased conditions at 0.01rad(Si)/s and at high dose rate under biased conditions at 55rad(Si)/s. The low dose rate test was run to 100krad(Si) and the high dose rate was run to 300krad(Si), with the low dose rate samples subjected to a high temperature anneal under bias at +100°C for 168 hours after irradiation. We encountered several failures, which are as follows:

At the 100krad(Si) level all 12 of the biased and grounded samples failed. These were marginal parametric failures and were for the A channel input LOW current exceeding the ±4µA limits. No further data is available (unfortunately including the input LOW current for the B channel input, which would be of interest) as the ATE testing stopped on first fail. As these were marginal failures the failed devices were retained in the test and were subjected to the post-irradiation anneal along with the passing parts; interestingly all samples easily met the ±4µA specification limits after anneal. The 100krad(Si) total dose level represents an overtest of 100% of the SMD rating of 50krad(Si) as opposed to the 50% overtest required by MIL-STD-883 Test Method 1019, and another test would be required to determine the anneal response after the SMD level.

The high dose rate samples showed no failures after 300krad(Si); no anneal was performed on these samples.

Figure 2 on page 3 shows the HIGH and LOW standby power supply current, which is the sum of both channels as both channels share common supply pins. Both parameters showed excellent stability and the post low dose rate anneal showed little effect.

Figure 3 on page 4 shows the LOW input current for each channel. Referring to previous comments we encountered a number of parametric failures after 100krad(Si) at low dose rate, with the samples recovering after anneal. The 300krad(Si) high dose rate test produced no failures.

Figure 4 on page 4 shows the HIGH input current for each channel. The parameter showed excellent stability and no anneal response.

Figure 5 on page 5 shows the output HIGH voltage referred to V_{DD} for each channel. The parameter showed excellent stability and no anneal response.

Figure 6 on page 5 shows the output HIGH voltage referred to ground for each channel. The parameter showed excellent stability and no anneal response.

Figure 7 on page 6 shows the output LOW voltage referred to V_{DD} for each channel. The parameter showed excellent stability and no anneal response.

Figure 8 on page 6 shows the output LOW voltage referred to ground for each channel. The parameter showed excellent stability and no anneal response.

Figures 9 and 10 on page 7 show the LOW-to-HIGH and the HIGH-to-LOW propagation delay, respectively, for each channel. The parameters showed excellent stability and no anneal response.

Figures 11 and 12 on page 8 show the output rise and fall time for each channel. These parameters showed excellent stability and no anneal response.

Given the parametric rejects encountered after 100krad(Si) of low dose rate irradiation, both biased and grounded, the part must be considered dose rate sensitive. The part is acceptance tested on a wafer-by-wafer basis to 300krad(Si) at a high dose rate (50 - 300rad(Si)/s) and to 50krad(Si) at a low dose rate (0.01rad(Si)/s), insuring hardness to the specified level for both dose rates. No significant differences in the low dose rate total dose response were noted between biased and grounded irradiation for any parameter.

Appendices

TABLE 3. REPORTED PARAMETERS AND THEIR POST-IRRADIATION LIMITS

FIGURE	PARAMETER	LIMIT, LOW	LIMIT, HIGH	UNITS	NOTES
2	Standby power supply current, HIGH and LOW	-	4	mA	Both channels
3	LOW input current	-4	4	µA	Each channel
4	HIGH input current	-4	4	µA	Each channel
5	Output HIGH voltage referenced to V_{DD}	-750	-	mV	Each channel
6	Output HIGH voltage referenced to ground	11.25	-	V	Each channel
7	Output LOW voltage referenced to V_{DD}	-	-11.2	V	Each channel
8	Output LOW voltage referenced to ground	-	800	mV	Each channel
9	LOW-to-HIGH propagation delay	-	350	ns	Each channel
10	HIGH-to-LOW propagation delay	-	350	ns	Each channel
11	Output rise time	-	95	ns	Each channel
12	Output fall time	-	95	ns	Each channel

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