Total dose and anneal testing of the ISL75052SEH low dropout regulator

Interim Report
Nick van Vonno
Intersil Corporation

Revision 0
10 June 2013

Table of Contents

1. Introduction and Executive Summary

This interim report discusses the results of low and high dose rate total dose testing of the ISL75052SEH low dropout regulator. The tests were conducted to provide an assessment of the total dose hardness of the part and its response to accelerated annealing. The high dose rate and anneal sequence is complete at the time of this report, while the ongoing low dose rate sequence has completed the 50 krad(Si) downpoint. Parts were irradiated under bias and with all pins grounded at low dose rate and at high dose rate. The high dose rate samples were also taken out to the 50% overtest (which is 150 krad(Si) in this case, as the part is rated at 100 krad(Si)) and subsequent anneal as described in MIL-STD-883 Test Method 1019. The high temperature anneal was performed under bias at an ambient temperature of 100^{o}C for 168 hours. The low dose rate samples will follow this same anneal sequence upon completion of the 150 krad(Si) irradiation. A final report will be issued upon completion of the low dose rate irradiations and subsequent anneal.

The ISL75052SEH is acceptance tested on a wafer by wafer basis to 300 krad(Si) at high dose rate (50 – 300 rad(Si)/s) and to 50 krad(Si) at low dose rate (0.01 rad(Si)/s), insuring hardness to the specified level for both dose rates.

The ISL75052SEH showed good performance over low and high dose rate irradiation at this intermediate point in the characterisation test. All samples passed the post-irradiation at all downpoint and following (for the high dose rate samples for the time being) the accelerated anneal procedure. The output voltage showed some rebound after the accelerated anneal, but in no case did the parametric values exceed the post-irradiation limits. We observed no significant dose rate sensitivity, and in fact the output voltage data shows high dose rate irradiation to be somewhat worst case, not an unexpected result for a largely CMOS component. No measurable differences in total dose response were noted between biased and grounded irradiation for any parameters.

This is an interim report, and a final version is expected to be released following the 150 krad(Si) low dose rate and anneal downpoints. This is expected to occur in Quarter 4 of 2013.

2. Reference Documents

MIL-STD-883 test method 1019.
ISL75052SEH data sheet.
Standard Microcircuit Drawing (SMD) 5962 – 13220

3: Part Description

The ISL75052SEH is a radiation hardened, single output low dropout regulator (LDO) specified for an output current of 1.5A. The device operates from an input voltage range of 4.0V to 13.2V and an output voltage range of 0.6V to 12.7V. The output voltage is adjustable based on an external resistor divider setting. Dropout voltages as low as 75mV (at 0.5A) typical can be realized using the device. This allows the user to improve system efficiency by lowering VIN to nearly VOUT. An ENABLE feature allows the part to be placed into a low shutdown current mode of 165μA (typical). When enabled, the ISL75052SEH operates with a low ground current of 11mA (typical), which provides operation with low quiescent power consumption. The device has superior transient response and is designed for predictable operation in the single-even effects (SEE) environment, including reduced single-event transient (SET) magnitude seen on the output. There is no need for additional protection diodes and filters.

A compensation (COMP) pin is provided to enable the use of external compensation. This is achieved by connecting a resistor and capacitor from the COMP pin to ground. The device is stable with tantalum capacitors as low as 47μF (KEMET T525 series) and provides excellent voltage regulation from no load to full load. The programmable soft-start function allows the user to program the inrush current by means of the decoupling capacitor used on the Bypass (BYP) pin. The overcurrent protection (OCP) pin allows the short circuit output current limit threshold to be programmed by means of a resistor from the OCP pin to ground. The OCP setting range is from 0.16A minimum to 3.2A maximum. The external resistor sets the constant current threshold for the output under fault conditions.

A thermal shutdown function disables the output if the device temperature exceeds a specified value; the ISL75052SEH will subsequently enter an ON/OFF (hiccup) cycle until the fault is removed. The ISL75052SEH is available in a 16 lead hermetic ceramic flatpack and in die form. The part offers guaranteed performance over the full -55^{o}C to +125^{o}C military temperature range. Key features and specifications follow.

- Input supply voltage range	4.0V to 13.2V
- Output current	1.5A at T_j = +150^{o}C
- Shutdown current	165µA typical
- Output voltage accuracy	± 1.5%, note 1
- Dropout voltage	75mV typical (0.5A)
- Dropout voltage	225mV typical (0.5A)
- Output noise voltage	100 µV rms typical, 300Hz to 300KHz
- Power supply rejection ratio	65dB typical at 1KHz
- Enable, PGOOD and programmable softstart features	
- Overtemperature shutdown and adjustable overcurrent protection	
- Operating temperature range	-55°C to +125°C
- 16 – lead hermetic flatpack	
- Total dose rating (50 – 300rad(Si)/s)	100krad(Si)
- Total dose rating (0.01rad(Si)/s)	100krad(Si)
- SET/SEL/SEB linear energy transfer rating	86MeV.cm^2/mg

Note 1: The output voltage accuracy of ± 1.5% is specified over line, load and temperature.

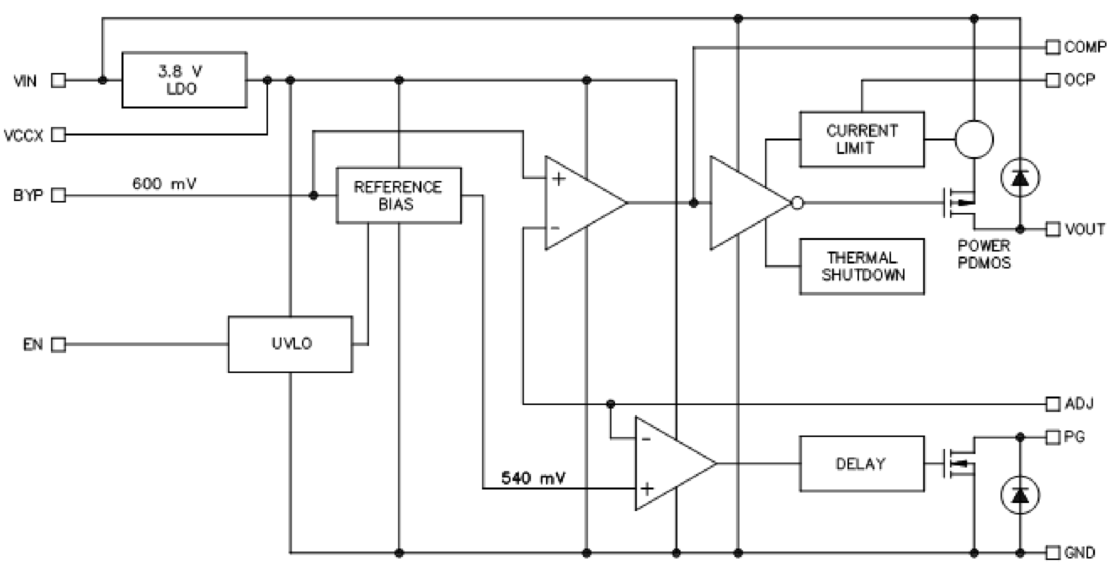

Figure 1: ISL75052SEH block diagram.

4: Test Description

4.1 Irradiation Facilities

High dose rate testing was performed at 71.9 rad(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 low dose rate ^{60}Co irradiator. The post-high dose rate biased anneal operations were performed in a small temperature chamber.

4.2 Test Fixturing

Figure 2 shows the configuration used for biased irradiation. The grounded irradiations were performed in the same fixture type with all pins hardwired to ground.

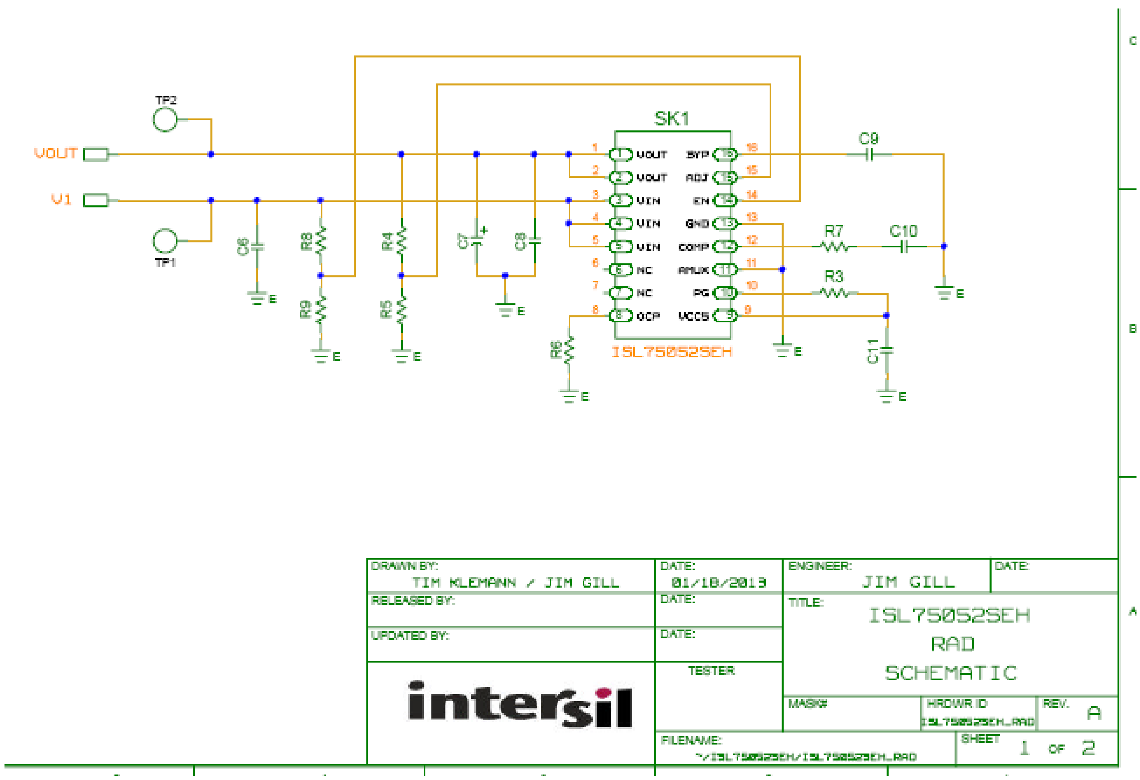

Figure 2: Biased and unbiased (grounded) irradiation bias configurations for the ISL75052SEH.

4.3 Characterization equipment and procedures

All electrical testing was performed outside the irradiator using the production automated test equipment (ATE) with datalogging at each downpoint. All downpoint electrical testing was performed at room temperature. Three control units were used to improve repeatability.

4.4 Experimental matrix

The experimental matrix consisted of 18 samples irradiated at low dose rate under bias, 20 samples irradiated at low dose rate with all pins grounded, 5 samples irradiated at high dose rate under bias and 7 samples irradiated at high dose rate with all pins grounded. Samples of the ISL75052SEH were drawn from preproduction lot WXT5J and were packaged in the hermetic 16-pin ceramic flatpack (package code KCG) package, which has an electrically grounded lid and a metallized bottom. 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.

4.5 Downpoints

Downpoints to date for the low dose rate tests were zero, 25 and 50 krad(Si); the test will be continued to the 100 and 150krad(Si) downpoints and will be followed by a 168 – hour anneal under bias at 100°C. Downpoints for the high dose rate test were zero, 25, 50, 100 and 150 krad(Si) followed by a 168 – hour anneal under bias at 100°C. The high dose rate test and anneal sequence is complete at the time of this writing.

5: Results

5.1 Test results

Table 1 shows the attributes data for the test. No rejects to the post-irradiation SMD limits were encountered at any downpoint including the high temperature anneals.

Table 1: ISL75052SEH total dose test attributes data.

Dose rate	Bias	Sample size	Downpoint	Pass (Note1)	Rejects
0.01 rad(Si)/s	Figure 2	18	0	18	0
			25 krad(Si)	18	0
			50 krad(Si)	18	0
			100 krad(Si)	18	0
			150 krad(Si)	18	0
			Anneal, 168h at 100°C	18	0
0.01 rad(Si)/s	Grounded	20	0	20	0
			25 krad(Si)	20	0
			50 krad(Si)	20	0
			100 krad(Si)	20	0
			150 krad(Si)	20	0
			Anneal, 168h at 100°C	20	0
71.9 rad(Si)/s	Figure 2	5	0	5	0
			25 krad(Si)	5	0
			50 krad(Si)	5	0
			100 krad(Si)	5	0
			150 krad(Si)	5	0
			Anneal, 168h at 100°C	5	0
71.9 rad(Si)/s	Grounded	7	0	7	0
			25 krad(Si)	7	0
			50 krad(Si)	7	0
			100 krad(Si)	7	0
			150 krad(Si)	7	0
			Anneal, 168h at 100°C	7	0

Note 1: 'Pass' indicates a sample that passes all post-irradiation SMD limits.
Note 2: The 168-hour anneal was performed at 100°C under bias as shown in Figure 2.

5.2 Variables data

The plots in Figures 3 through 25 show data at all downpoints including the post-anneal data. The plots show the response to total dose irradiation at low dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases and at high dose rate for the biased (Fig.2) and unbiased cases. In addition the plots show the response of the high dose rate samples to a post-irradiation anneal at 100^{o}C for 168 hours for the completed high dose rate test. A final report will be issued upon completion of the low dose rate irradiations and subsequent anneal. We chose to plot the median for these parameters due to the relatively small sample sizes. Section 6 will provide individual discussion of the figures.

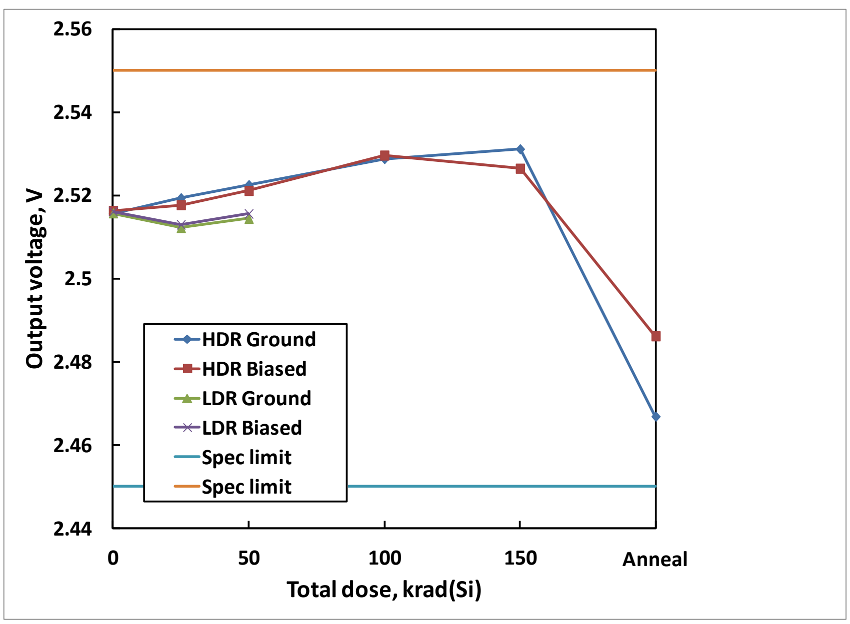

Figure 3: ISL75052SEH output voltage accuracy, 4.0V in, 2.5V out, no load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are 2.45V to 2.55V.

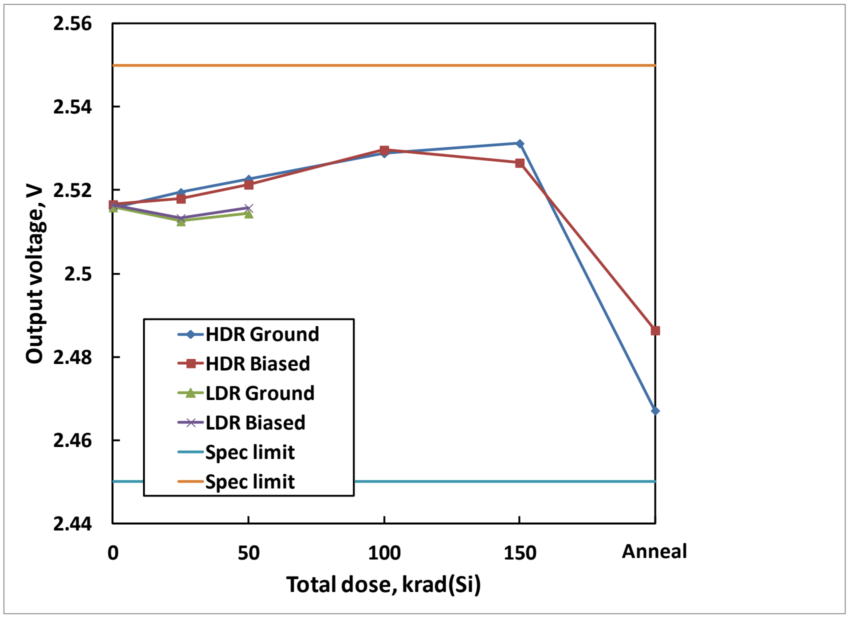

Figure 4: ISL75052SEH output voltage accuracy, 4.0V in, 2.5V out, 1.5A load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are 2.45V to 2.55V.

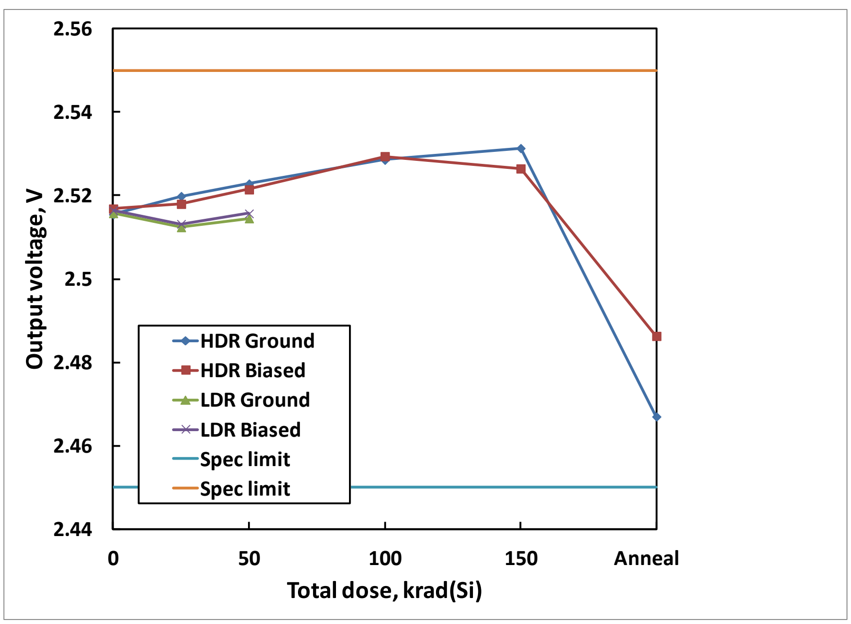

Figure 5: ISL75052SEH output voltage accuracy, 5.0V in, 2.5V out, no load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are 2.45V to 2.55V.

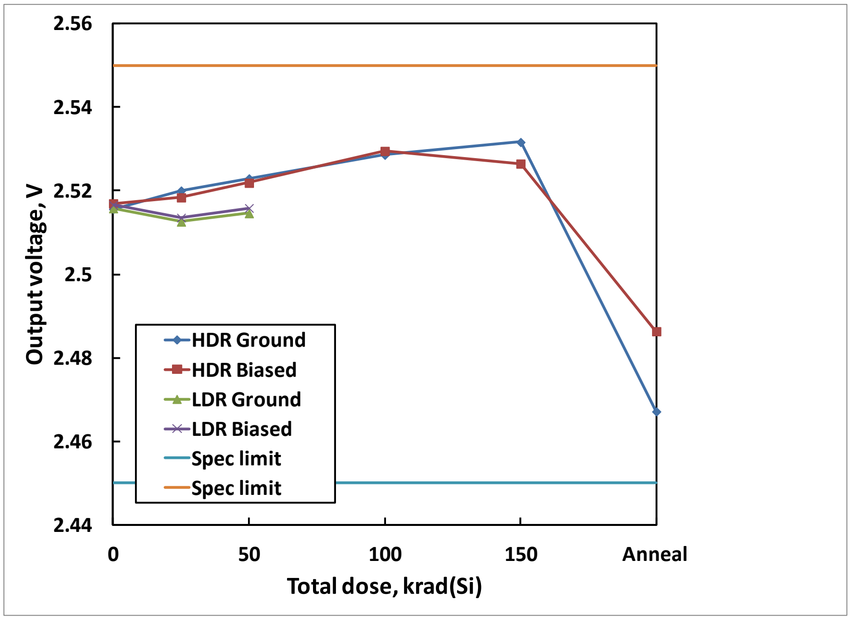

Figure 6: ISL75052SEH output voltage accuracy, 5.0V in, 2.5V out, 1.5A load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are 2.45V to 2.55V.

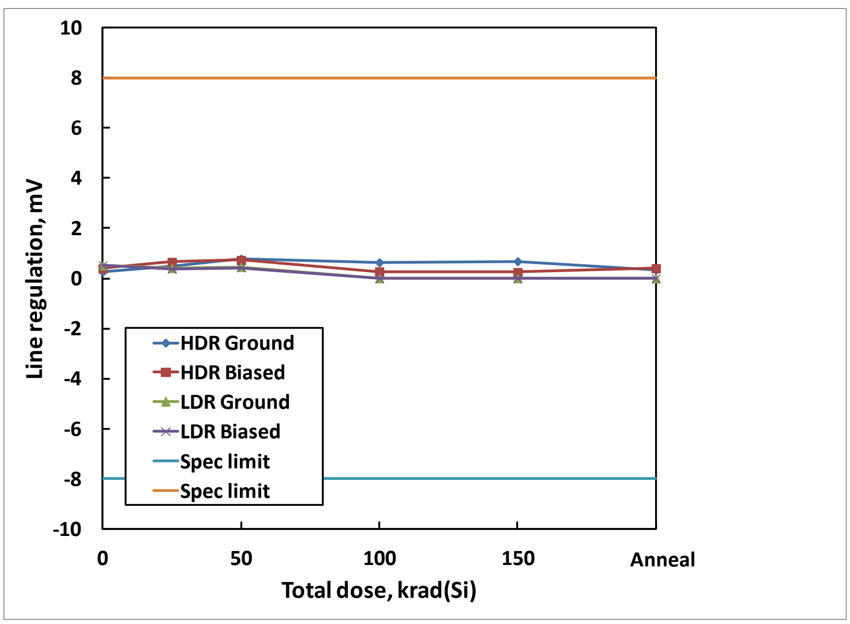

Figure 7: ISL75052SEH line regulation, 2.5V out, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are -8.0 to 8.0mV.

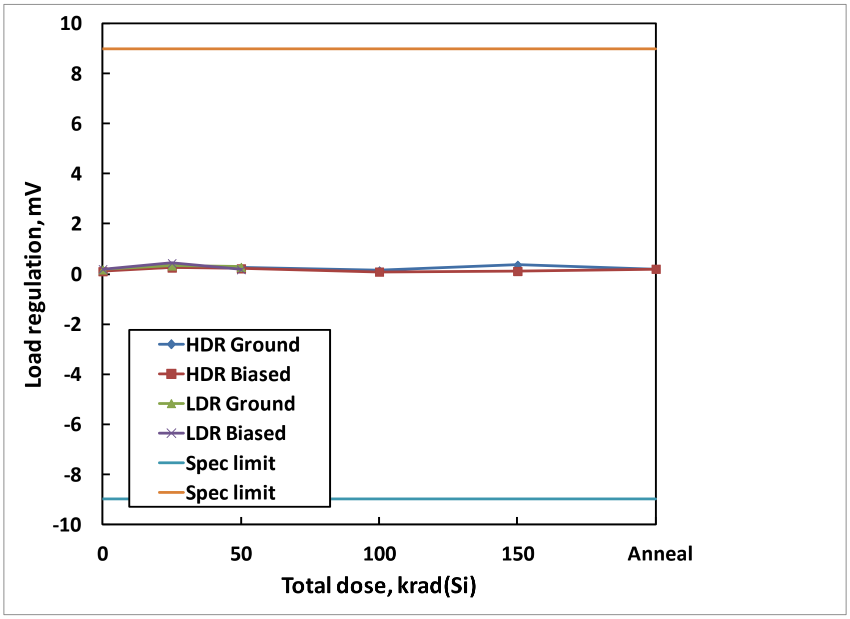

Figure 8: ISL75052SEH load regulation, 2.5V out, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are -9.0mV to 9.0mV.

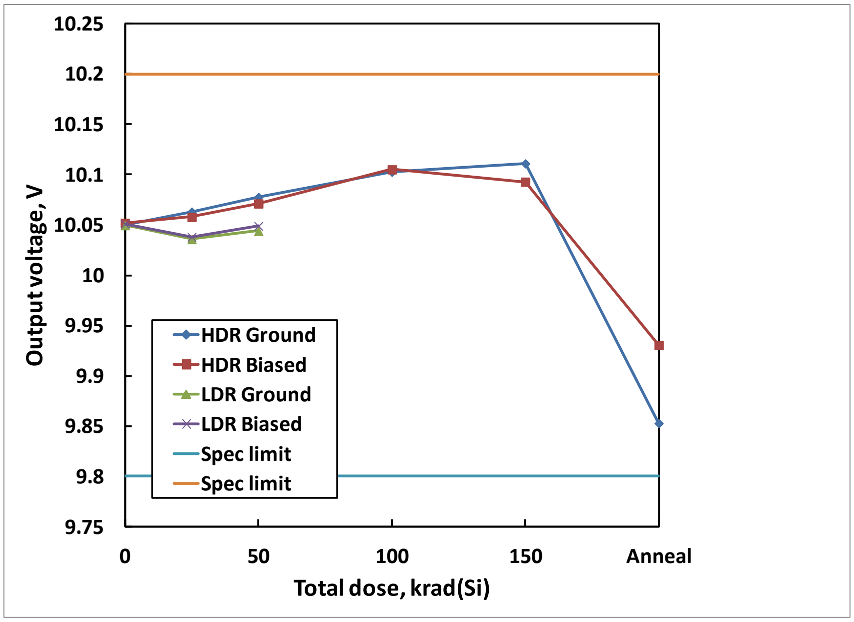

Figure 9: ISL75052SEH output voltage accuracy, 10.5V in, 10.0V out, no load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are 9.8V to 10.2V.

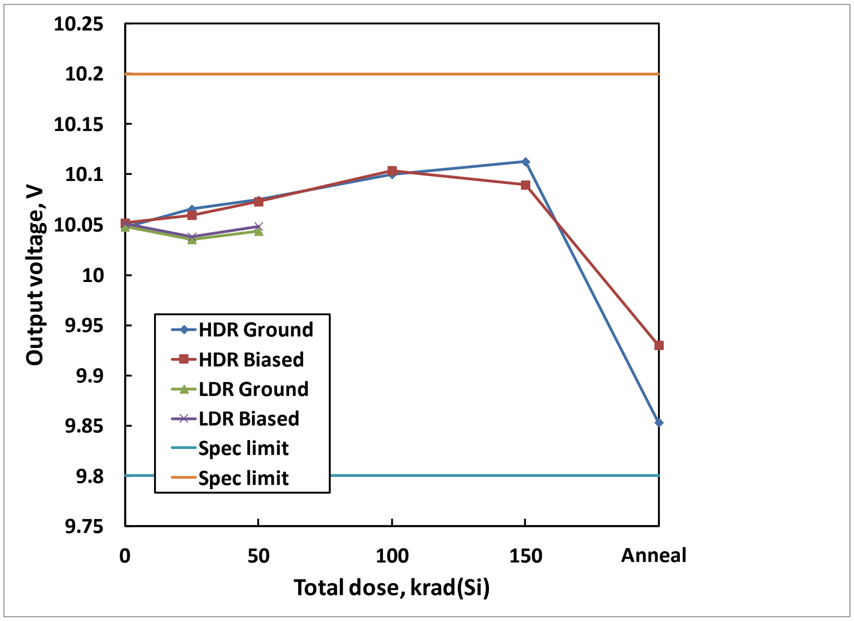

Figure 10: ISL75052SEH output voltage accuracy, 10.5V in, 10.0V out, 1.5A load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are 9.8V to 10.2V.

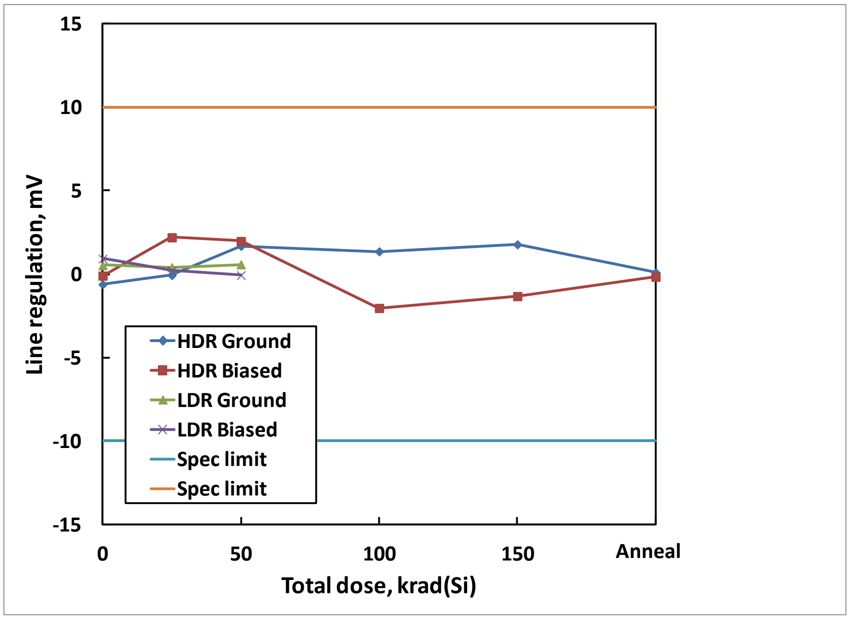

Figure 11: ISL75052SEH line regulation, 10.0V out, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are -10.0mV to 10.0mV.

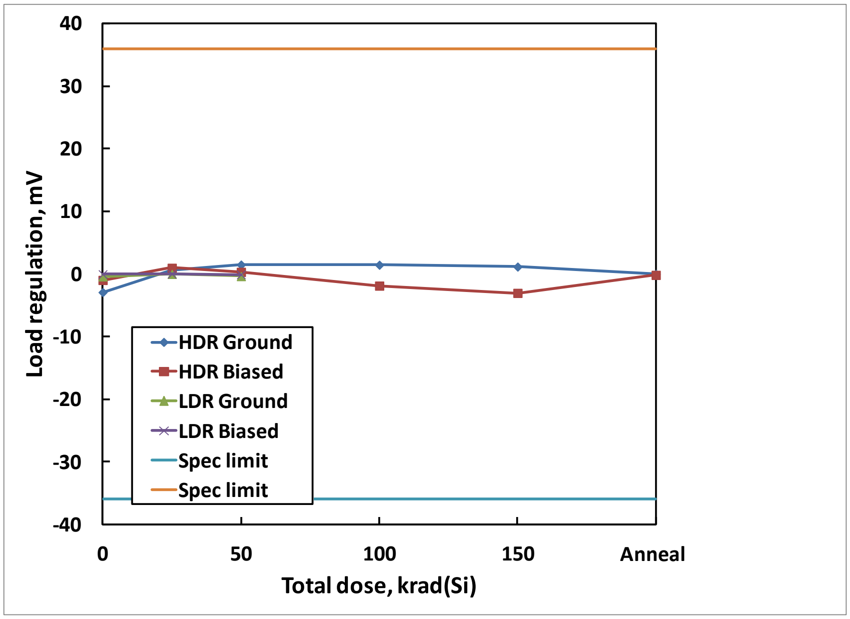

Figure 12: ISL75052SEH load regulation, 10.0V out, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are -36.0mV to 36.0mV.

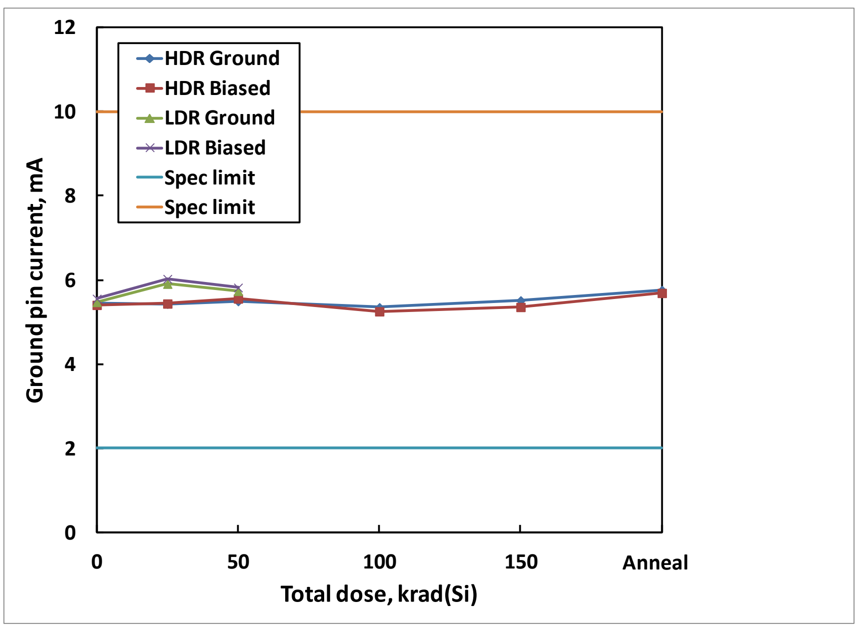

Figure 13: ISL75052SEH ground pin current, 4.0V in, 2.5V out, no load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 10.0mA maximum; the 2.0mA specification is an ATE limit.

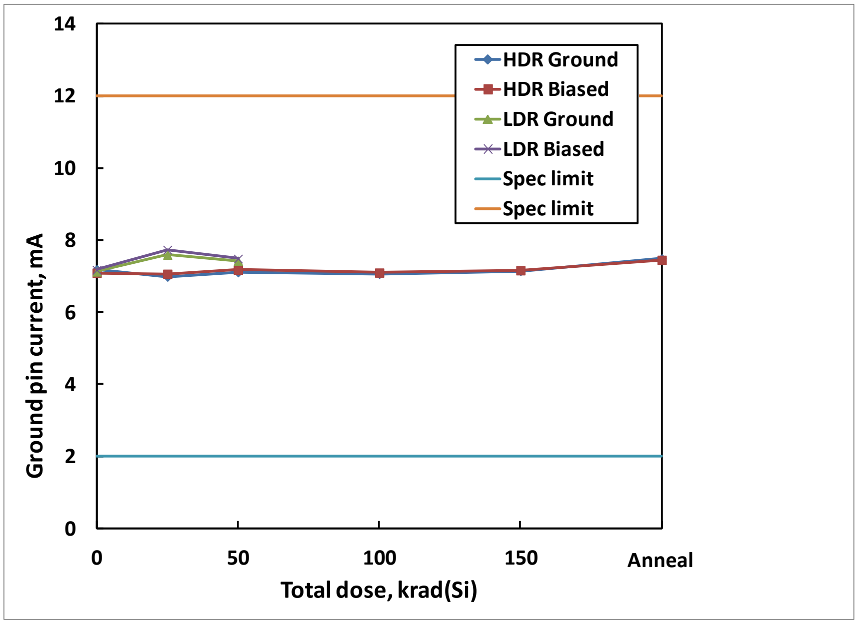

Figure 14: ISL75052SEH ground pin current, 4.0V in, 2.5V out, 1.5A load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 12.0mA maximum; the 2.0mA specification is an ATE limit.

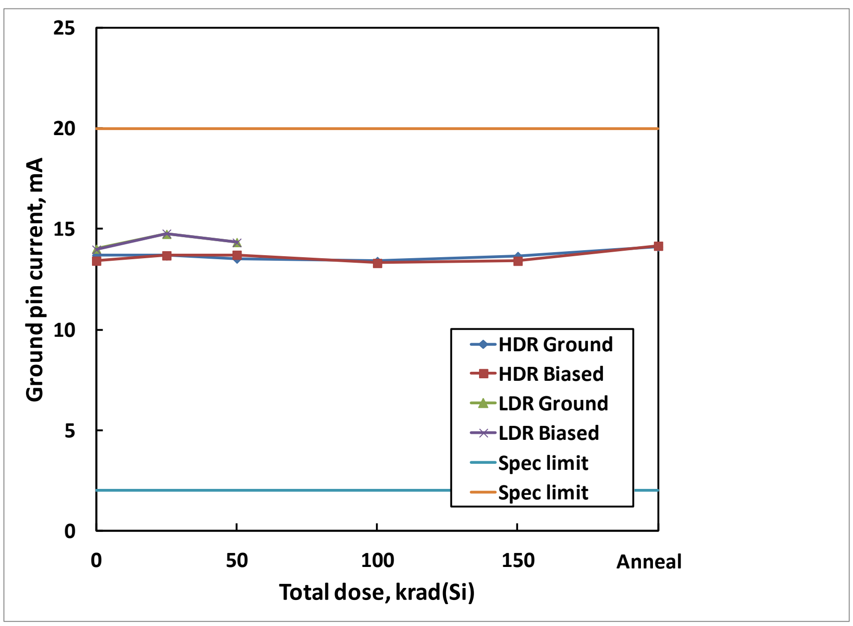

Figure 15: ISL75052SEH ground pin current, 10.5V in, 10.0V out, no load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 20.0mA maximum; the 2.0mA specification is an ATE limit.

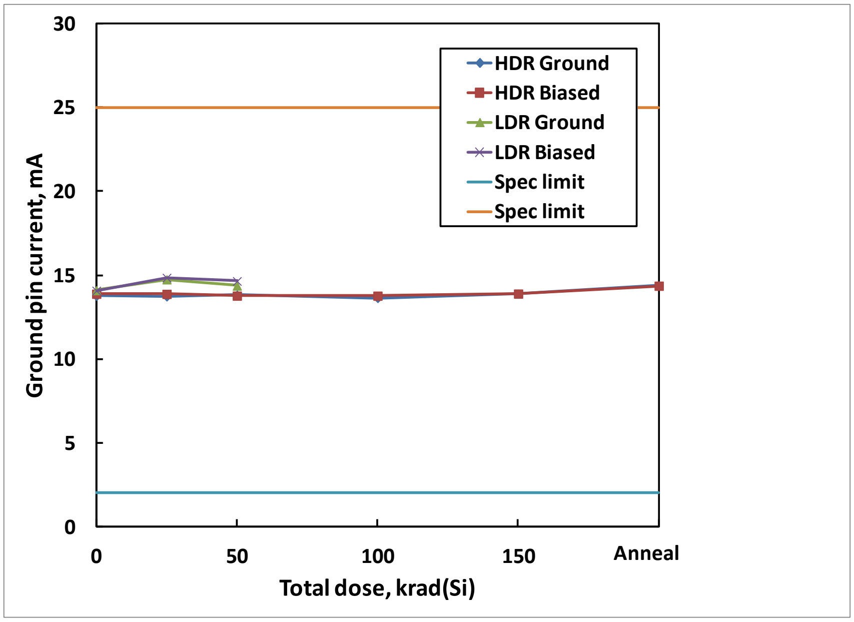

Figure 16: ISL75052SEH ground pin current, 10.5V in, 10.0V out, 1.5A load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 25.0mA maximum; the 2.0mA specification is an ATE limit.

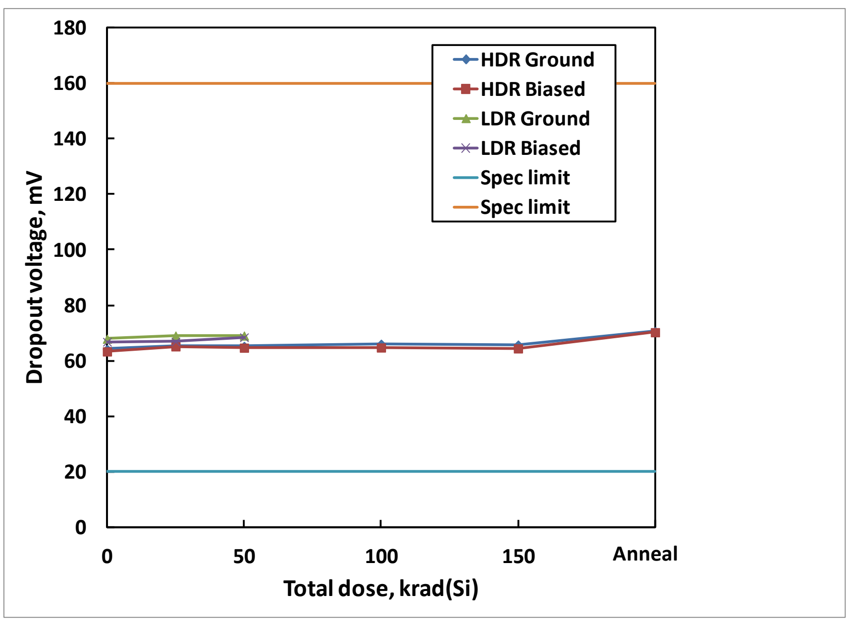

Figure 17: ISL75052SEH dropout voltage, 3.6V out, 500mA load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 160.0mV maximum; the 20mV specification is an ATE limit.

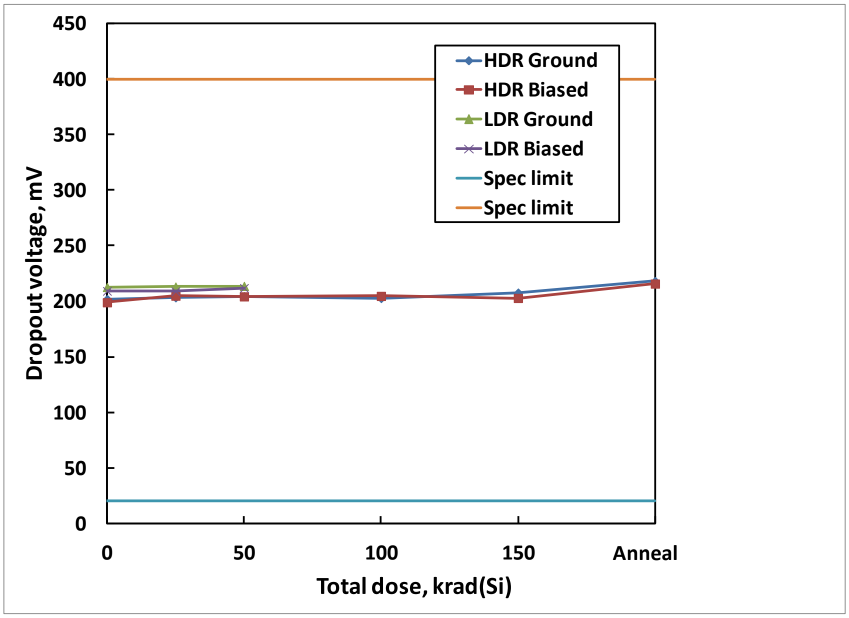

Figure 18: ISL75052SEH dropout voltage, 3.6V out, 1500mA load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 400.0mV maximum; the 20mV specification is an ATE limit.

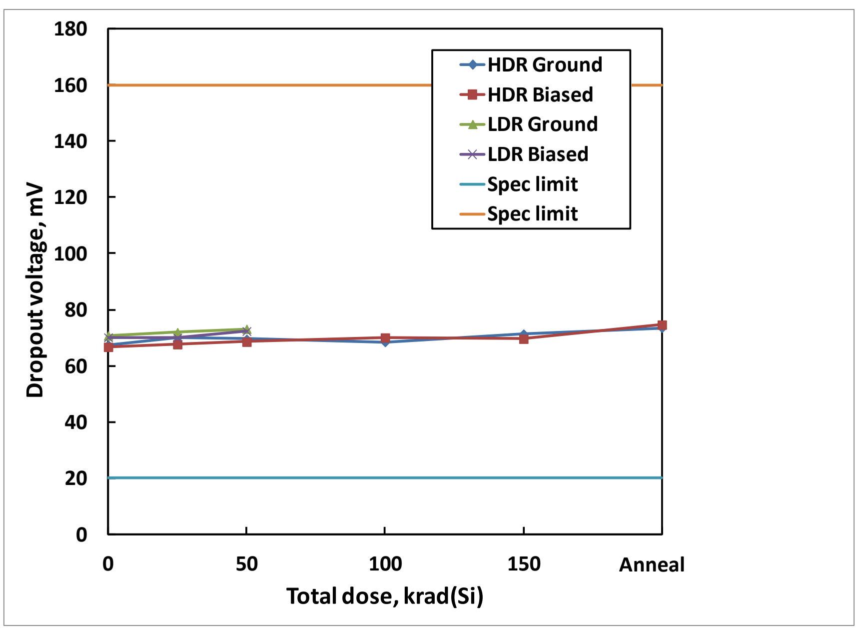

Figure 19: ISL75052SEH dropout voltage, 12.7V out, 500mA load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 160.0mV maximum; the 20mV specification is an ATE limit.

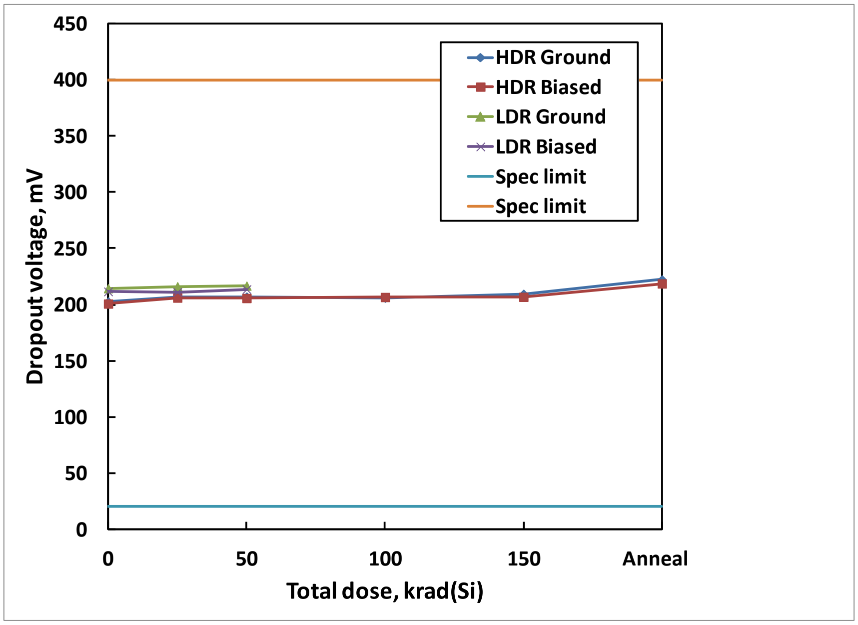

Figure 20: ISL75052SEH dropout voltage, 12.7V out, 1500mA load, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 400.0mV maximum; the 20mV specification is an ATE limit.

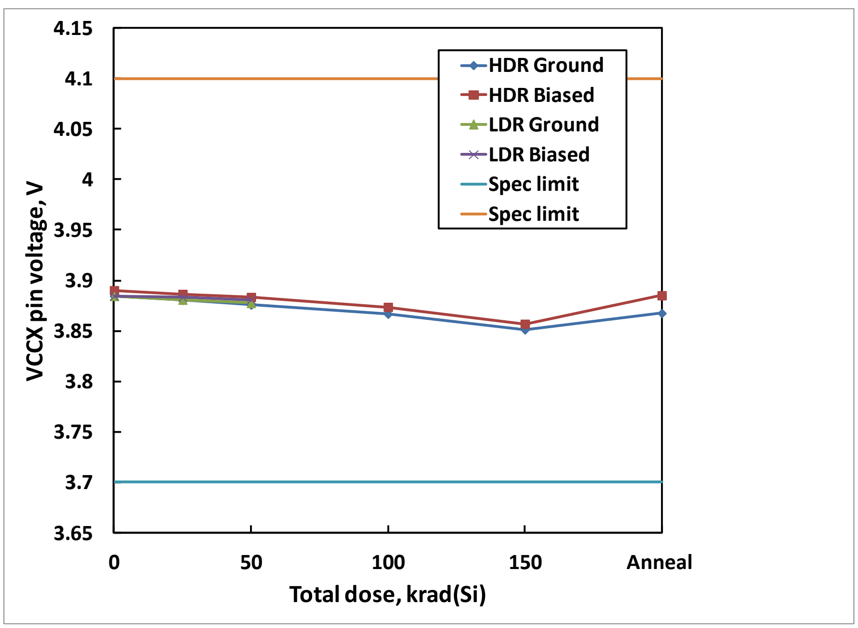

Figure 21: ISL75052SEH VCCX pin voltage, 4.0V input, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are 3.7V to 4.1V.

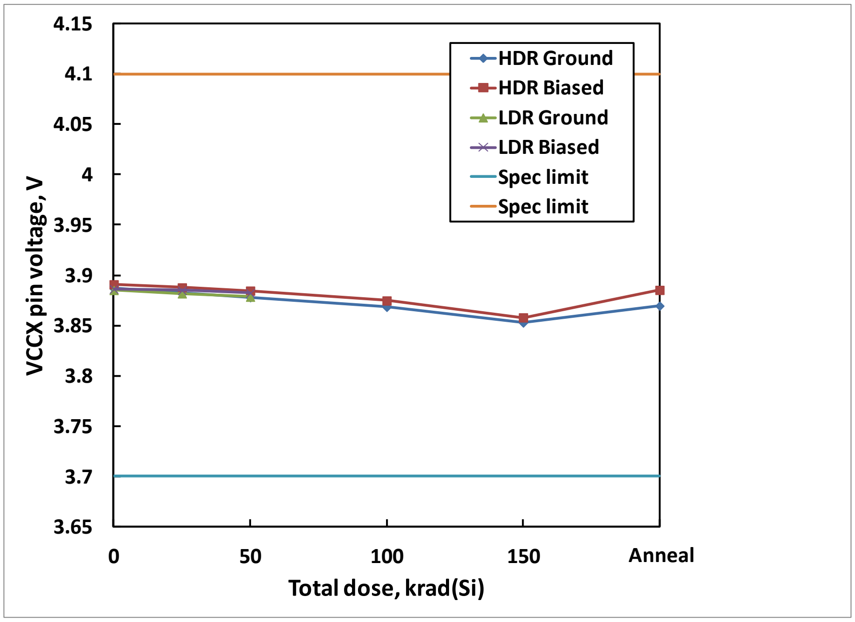

Figure 22: ISL75052SEH VCCX pin voltage, 13.2V input, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limits are 3.7V to 4.1V.

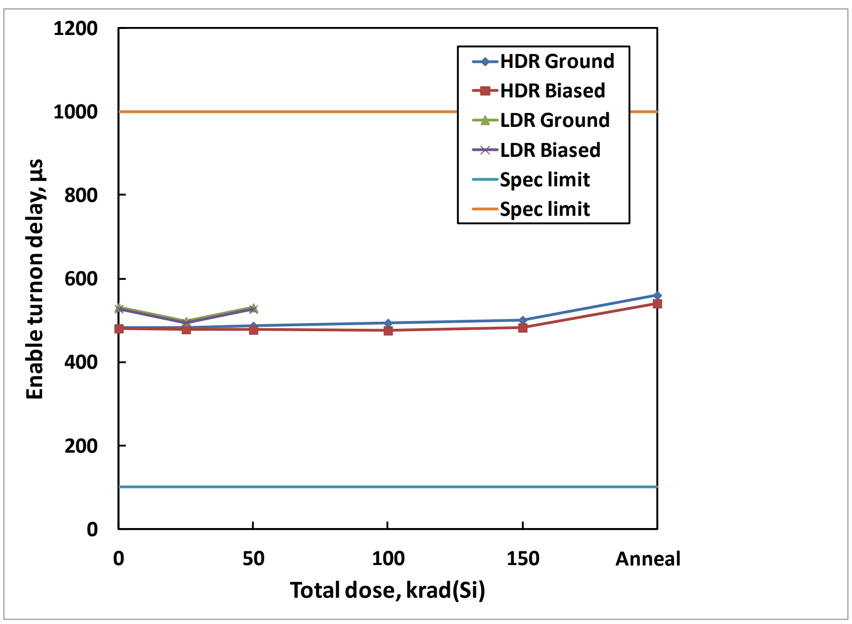

Figure 23: ISL75052SEH enable turnon delay as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 1000.0µs (1.0ms) maximum; the 100.0µs specification is an ATE limit.

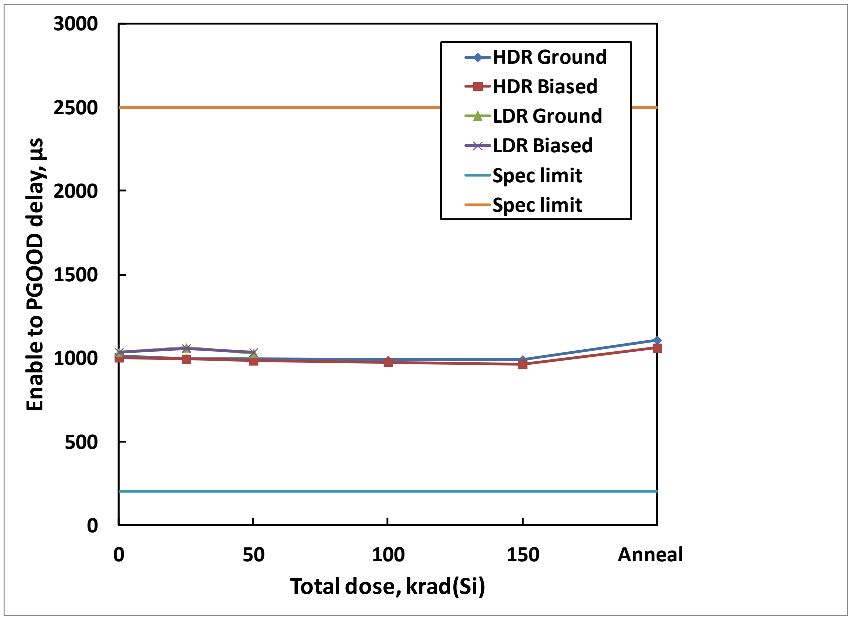

Figure 24: ISL75052SEH enable to PGOOD turnon delay, 22µF output capacitor, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 2500.0µs (2.5ms) maximum; the 200.0µs specification is an ATE limit.

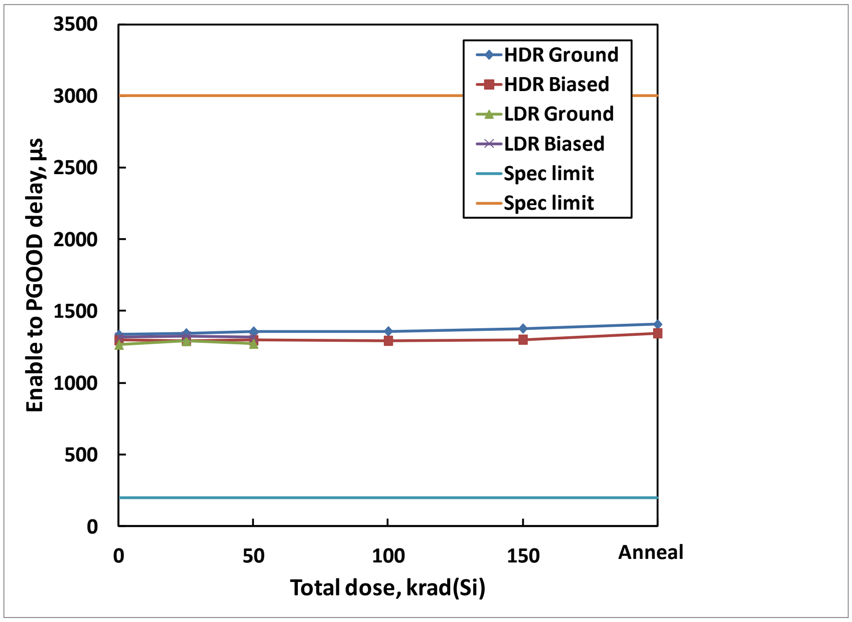

Figure 25: ISL75052SEH enable to PGOOD delay, 200µF output capacitor, as a function of total dose irradiation at low and high dose rate for the biased (per Figure 2) and unbiased (all pins grounded) cases. The dose rate was 0.01 rad(Si)/s for low dose rate irradiation and 71.9 rad(Si)/s for high dose rate irradiation. The high dose rate irradiation was followed by a high temperature anneal; the low dose rate test is still in progress and will be followed by an anneal as well. Sample sizes were 18 at low dose rate under bias, 20 at low dose rate with all pins grounded, 5 samples at high dose rate under bias and 7 samples at high dose rate with all pins grounded. The post-irradiation specification limit is 3000.0µs (3.0ms) maximum; the 200.0µs specification is an ATE limit.

6: Discussion and conclusion

This document reports the results of low and high dose rate testing of the ISL75052SEH low dropout regulator. Parts were irradiated under bias and with all pins grounded at low and high dose rate in accordance with the MIL-STD-883 Test Method 1019.7 dose rate sensitivity protocol, at 0.01 rad(Si)/s and 71.9 rad(Si)/s respectively. At the time of this interim report the low dose rate test has been run to 50krad(Si) and the high dose rate test is complete through 150 krad(Si), with the high dose rate samples subjected to a high temperature anneal under bias at 100°C for 168 hours. A similar anneal cycle will be performed on the low dose rate samples after completion of 150 krad(Si) at low dose rate. All parameters remained within the SMD and data sheet post-irradiation limits at all downpoints. The part has a large number of measured parameters, so we have summarized the results in a table of attributes data (5.1) followed by a limited number of curves of interest (5.2, 23 figures). We will discuss each of the figures separately.

Figs. 3 through 6, output voltage: These plots show the output voltage of the regulator for the 4.0V in/2.5V out/no load, the 4.0V in/2.5V out/1.5A load, 5.0V in/2.5V out/no load and 5.0V in/2.5V out/1.5A load cases. All four plots show excellent stability over the 50 krad(Si) at low dose rate that has been accrued to date. The high dose rate curves show good stability over the 150 krad(Si) irradiation but then show a substantial rebound of some 60mV over the 100°C/168h anneal. The grounded irradiation is worst case by a small margin. This 'rebound' behaviour over high temperature biased anneal is typical of CMOS technology, and the ISL75052SEH is largely implemented in CMOS.

Quoting from MIL-STD-883 Test Method 1019: 'The accelerated annealing test provides an estimate of worst-case degradation of MOS microcircuits in low dose rate environments.' The annealing test includes a 50% overtest: 'Irradiate each test device to an additional 0.5-times the specified dose using the standard test conditions (3.1 through 3.10). Note that no electrical testing is required at this time.'

While this language is not specific as to the exact (low) dose rate of interest in this estimation procedure, we note that the ISL75052SEH has been thoroughly tested at the TM1019 low dose rate of 0.01rad(Si)/s (see this report, with sample sizes of 18 and 20, respectively, for the biased and unbiased cases), and that there is hence no need for 'estimates' of the low dose rate response. Additionally the part is acceptance tested on a wafer by wafer basis on a production basis, providing additional radiation hardness assurance. Finally TM1019 is silent on what constitutes a pass or fail situation for this procedure, which implies that it serves informational purposes only. We further note that the post-rebound parametric values in no case exceeded the SMD post- radiation limits during these tests.

Figs. 7 and 8, line regulation and load regulation: These plots show line and load regulation at 2.5V output voltage. Both parameters showed excellent stability with no measurable differences in response between the two dose rates.

Figs. 9 and 10, output voltage: Here we plot the output voltage for the 10.5V in/10.0V out/no load and the 10.5V in/10.0V out/1.5A load cases and negative input bias current. As in Figs. 3 through 6 we note the same substantial rebound of some 60mV over the 100°C/168h anneal. The low dose rate data showed excellent stability.

Figs. 11 and 12, line regulation and load regulation: These plots show line and load regulation at 10.0V output voltage. Both parameters showed excellent stability with no measurable differences in response between the two dose rates.

Figs. 13 through 16, ground pin current: These plots show the ground pin current for the 4.0V in/2.5V out/no load, the 4.0V in/2.5V out/1.5A load, 10.5V in/10.0V out/no load and 10.5V in/10.0V out/1.5A load cases. This is a key parameter in LDO performance as it represents the operating current of the device and directly affects efficiency. The parameter showed excellent stability for all four conditions, with no measurable differences in response between the two dose rates.

Figs. 17 through 20, dropout voltage: These plots show the dropout voltage at 3.6V out/500mA load current, 3.6V out/1500mA load current, 12.7V out/500mA load current and 12.7V out/1500mA load current.

This is again a key specification as it directly affects operating conditions and efficiency. The parameters showed excellent stability for all four conditions with no measurable differences in response between the two dose rates.

Figs. 21 and 22, VCCX pin voltage: These plots show the VCCX pin voltage at 4.0V in and 13.2V in, which represents the range of recommended input voltages. The VCCX pin represents the output of the on-chip 3.8V low dropout regulator used to provide a stable supply voltage for the rest of the chip's circuitry, see Figure 1. Both parameters showed excellent stability with no measurable differences in response between the two dose rates.

Fig. 23, enable turnon delay: This plot shows the propagation delay from a 1.2V enable step to V_{out} = 100mV, representing the turnon time of the regulator. The measurement is taken at 4.5V in, 4.0V out and 1.5A load current, with a load capacitor of 22µF and a bypass capacitor of 0.2µF. The parameter showed excellent stability with no measurable differences in response between the two dose rates.

Figs. 24 and 25, enable to PGOOD delay: These two plots show the propagation delay from enable to the PGOOD status flag, again measured at 4.5V in, 4.0V out and 1.5A load current, with a load capacitor of 22µF (Fig. 20) or 200uF (Fig. 21) and a bypass capacitor of 0.2µF for both cases. Both parameters showed excellent stability with no measurable differences in response between the two dose rates.

The ISL75052SEH showed good performance over low and high dose rate irradiation at this intermediate point in the characterisation test. All samples passed the post-irradiation at all downpoint and following (for the high dose rate samples for the time being) the accelerated anneal procedure. The output voltage showed some rebound after the accelerated anneal, but in no case did the parametric values exceed the post-irradiation limits. The part is acceptance tested on a wafer by wafer basis to 300 krad(Si) at high dose rate (50 – 300 rad(Si)/s) and to 50 krad(Si) at low dose rate (0.01 rad(Si)/s), insuring hardness to the specified level for both dose rates. We observed no significant dose rate sensitivity, and in fact the output voltage data shows high dose rate to be somewhat worst case, which should not be an unexpected result for a largely CMOS component. No measurable differences in the total dose response were noted between biased and grounded irradiation for any parameters.

This is an interim report, and a final version is expected to be released following the 150krad(Si) low dose rate and anneal downpoints. This is expected to occur in Quarter 4 of 2013.

7: Appendices

7.1: Reported parameters and their post-irradiation limits:

Fig.	Parameter	Limit, low	Limit, high	Units	Notes
3	Output voltage, 4.0V in, 2.5V out, no load	2.45	2.55	V	
4	Output voltage, 4.0V in, 2.5V out, 1.5A load	2.45	2.55	V	
5	Output voltage, 5.0V in, 2.5V out, no load	2.45	2.55	V	
6	Output voltage, 5.0V in, 2.5V out, 1.5 load	2.45	2.55	V	
7	Line regulation, 2.5V out	-8.0	8.0	mV	
8	Load regulation, 2.5V out	-9.0	9.0	mV	
9	Output voltage, 10.5V in, 10.0V out, no load	2.45	2.55	V	
10	Output voltage, 10.5V in, 10.0V out, 1.5A load	2.45	2.55	V	
11	Line regulation, 10.0V out	-10.0	10.0	mV	
12	Load regulation, 10.0V out	-36.0	36.0	mV	
13	Ground pin current, 4.0V in, 2.5V out, no load	-	10.0	mA	
14	Ground pin current, 4.0V in, 2.5V out, 1.5A load	-	12.0	mA	
15	Ground pin current, 10.5V in, 10.0V out, no load	-	20.0	mA	
16	Ground pin current, 10.5V in, 10.0V out, 1.5A load	-	25.0	mA	
17	Dropout voltage, 3.6V out, 500mA	-	160.0	mV	
18	Dropout voltage, 3.6V out, 1500mA	-	400.0	mV	
19	Dropout voltage, 12.7V out, 500mA	-	160.0	mV	
20	Dropout voltage, 12.7V out, 1500mA	-	400.0	mV	
21	VCCX pin voltage, 4.0V in	3.7	4.1	V	
22	VCCX pin voltage, 13.2V in	3.7	4.1	V	
23	Enable turnon delay	-	1000.0	µs	
24	Enable to PGOOD delay	-	2500.0	µs	C_{OUT} = 22µF
25	Enable to PGOOD delay	-	3000.0	µs	C_{OUT} = 200µF

8: Document revision history

Revision	Date	Pages	Comments
0	June 2013	All	Original issue