Total dose testing of the IS-1009EH Voltage Reference

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Revision 0
January 2014

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1. Introduction

This report reports the results of a low and high dose rate total dose test of the IS-1009EH shunt voltage reference. The test was conducted in order to determine the sensitivity of the part to the total dose environment and to determine if dose rate and bias sensitivity exist. It should be noted that these samples were taken from an Intersil Palm Bay Fab 59 production lot that used Silox passivation as opposed to the silicon nitride used in earlier production, and evaluating the effects of this process change was an added objective of this work. Two fabrication lots were tested. For lot DPM0JEHA the low dose rate irradiations were followed by a 100^o biased anneal for 168 hours, with data taken after anneal. For lot G2A8CECH the low dose rate irradiations were followed by a 24 hour biased anneal at room temperature, which was then followed by a 100^o biased anneal for 168 hours; this protocol addresses the requirements of ESA specification 22900, 'Total Dose Steady-State Irradiation'. Data for lot G2A8CECH was taken after low dose rate irradiation, before and after the RT anneal and then again after the HT anneal.

The IS-1009RH and IS-1009EH use the same die and differ only in the passivation technology and total dose acceptance testing flow, which is performed on a wafer by wafer basis. The IS-1009EH uses silicon dioxide ('silox') passivation while the IS-1009RH uses silicon nitride ('nitride') passivation. Additionally the IS-1009EH is acceptance tested at low and high dose rate, while the IS-1009RH is acceptance tested at high dose rate only.

2. Reference Documents

MIL-STD-883G test method 1019
IS-1009EH data sheet
DLA Standard Microcircuit Drawing (SMD) 5962-00523

3: Part Description

The IS-1009EH is a shunt voltage reference designed to provide an accurate 2.5V reference voltage over a wide current range. The device is stable over a wide current range and is designed to maintain stability over the full military temperature range and over time. It operates and is specified at a lower minimum current than other 1009 types. The 0.2% reference tolerance is achieved by on-chip trimming. An adjustment terminal is provided to allow for the calibration of system errors. The use of this terminal to adjust the reference voltage does not affect the temperature coefficient. Constructed in the Intersil dielectrically isolated EBHF process, the device is immune to single event latchup (and indeed immune to latchup from any source).

Specifications for radiation hardened QML devices are controlled by the Defense Logistics Agency, Land and Maritime (DLA). Detailed Electrical Specifications for the device are contained in SMD 5962-00523. The SMD number must be used when ordering, and a "hot-link" is provided on the Intersil homepage for downloading the document.

A block diagram of the IS-1009EH is not shown as the equivalent circuit of the part is a simple Zener diode, refer to Figure 1.

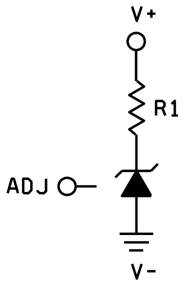
4: Test Description

4.1 Irradiation Facilities

High dose rate testing to 300 krad(Si) was performed using a Gammacell 220 ^{60}Co irradiator located in the Palm Bay, Florida Intersil facility. Low dose rate testing to 150 krad(Si) was performed using a Hopewell Designs (Alpharetta, GA) N40 panoramic ^{60}Co irradiator, also located in the Palm Bay facility. The high dose rate irradiations were done at 65 rad(Si)/s and the low dose rate work was performed at 0.010 rad(Si)/s, both per MIL-STD-883 Method 1019.7. The post low dose rate biased anneals were performed in a small temperature chamber.

4.2 Test Fixturing

Fig. 1 shows the configuration used for biased irradiation at both high and low dose rate. This bias configuration is in conformance with the SMD 5962-00523 configuration and was used for the post-irradiation anneals as well.



NOTES:

V+ = +5 V ±0.5 V
V- = GND
ADJ = Open
R1 = 2.5 kΩ, 5 %, 1/4 W

Fig. 1: Irradiation bias configuration for the IS-1009EH per Standard Microcircuit Drawing (SMD) 5962-00523.

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. Downpoint electrical testing was performed at room temperature.

4.4 Experimental matrix

Samples of the IS-1009EH die were drawn from production lots DPM0JEHA and G2A8CECH and were packaged in the 3-pad hermetic SMD.5 ceramic chip carrier production package. Samples were processed through the standard burnin cycle before irradiation, as required by MIL-STD-883, and were screened to the SMD 5962-00523 limits at room, low and high temperatures prior to the test.

The experimental matrix for fabrication lot DPM0JEHA consisted of 19 samples irradiated at high dose rate under bias, 8 samples irradiated at low dose rate with all pins grounded and 8 samples irradiated at low dose rate under bias. One control unit was used.

The experimental matrix for fabrication lot G2A8CECH consisted of 28 samples irradiated at high dose rate under bias, 14 samples irradiated at low dose rate with all pins grounded and 14 samples irradiated at low dose rate under bias. One control unit was used.

4.5 Downpoints

Downpoints were 0, 50 and 300 krad(Si) for the high dose rate tests and 0, 25, 50, 75, 100, 125 and 150 krad(Si) for the low dose rate tests. Two fabrication lots were tested. For lot DPM0JEHA the low dose rate irradiations were followed by a 100^{o}C biased anneal for 168 hours, with data taken after anneal. For lot G2A8CECH the low dose rate irradiations were followed by a 24 hour biased anneal at room temperature (RT), which was then followed by a 100^{o}C (HT) biased anneal for 168 hours. Data for this lot was taken at the low dose rate irradiation downpoints, before and after the RT anneal and then again after the HT anneal.

5: Results

5.1 Attributes data

Table 1: Attributes data for lot DPM0JEHA.

Part	Dose rate, rad(Si)/s	Bias	Sample size	Downpoint	Pass (Note 1)	Fail
IS-1009EH	0.01	Biased	8	Pre-irradiation	8	0
				25 krad(Si)	8	0
				50 krad(Si)	8	0
				75 krad(Si)	8	0
				100 krad(Si)	8	0
				125 krad(Si)	8	0
				150 krad(Si)	8	0
				HT anneal	8	0
IS-1009EH	0.01	Grounded	8	Pre-irradiation	8	0
				25 krad(Si)	8	0
				50 krad(Si)	8	0
				75 krad(Si)	8	0
				100 krad(Si)	8	0
				125 krad(Si)	8	0
				150 krad(Si)	8	0
				HT anneal	8	0
IS-1009EH	65	Biased	19	Pre-irradiation	19	0
				50 krad(Si)	19	0
				300 krad(Si)	19	0

Note 1: ‘Pass’ indicates a sample that passes all post-irradiation SMD limits.

Table 2: Attributes data for lot G2A8CECH.

Part	**Dose rate, rad(Si)/s**	**Bias**	**Sample size**	**Downpoint**	**Pass (Note 1)**	**Fail**
IS-1009EH	0.01	Biased	14	Pre-irradiation	14	0
				25 krad(Si)	14	0
				50 krad(Si)	14	0
				75 krad(Si)	14	0
				100 krad(Si)	14	0
				125 krad(Si)	14	0
				150 krad(Si)	14	0
				RT anneal	14	0
				HT anneal	14	0
IS-1009EH	0.01	Grounded	14	Pre-irradiation	14	0
				25 krad(Si)	14	0
				50 krad(Si)	14	0
				75 krad(Si)	14	0
				100 krad(Si)	14	0
				125 krad(Si)	14	0
				150 krad(Si)	14	0
				RT anneal	14	0
				HT anneal	14	0
IS-1009EH	65	Biased	28	Pre-irradiation	28	0
				50 krad(Si)	28	0
				300 krad(Si)	28	0

Note 1: ‘Pass’ indicates a sample that passes all post-irradiation SMD limits.

5.2 Variables data

The plots in Figs. 2 through 9 show variables data at all downpoints. The plots show the average, minimum and maximum of key parameters for both tests as a function of total dose for each of the three irradiation conditions and the post-irradiation anneals.

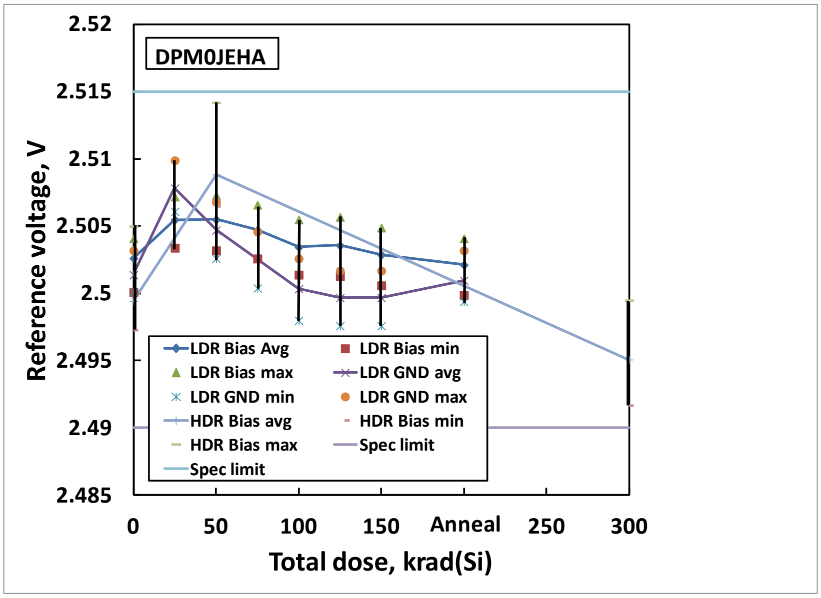


Fig. 2: IS-1009EH fab lot DPM0JEHA reference output voltage at 1mA as a function of total dose irradiation at low dose rate for the unbiased (all pins grounded) and the biased (per Fig. 1) cases and at high dose rate for the biased (also per Fig. 1) case. The low dose rate irradiations were followed by a biased anneal at 100^{o}C for 168 hours. The low dose rate was 0.01 rad(Si)/s and the high dose rate 65 rad(Si)/s. Sample size for each of the two low dose rate cells was 8 each, while the high dose rate cell had 19 samples. The post-irradiation SMD limits are 2.490V to 2.515V.

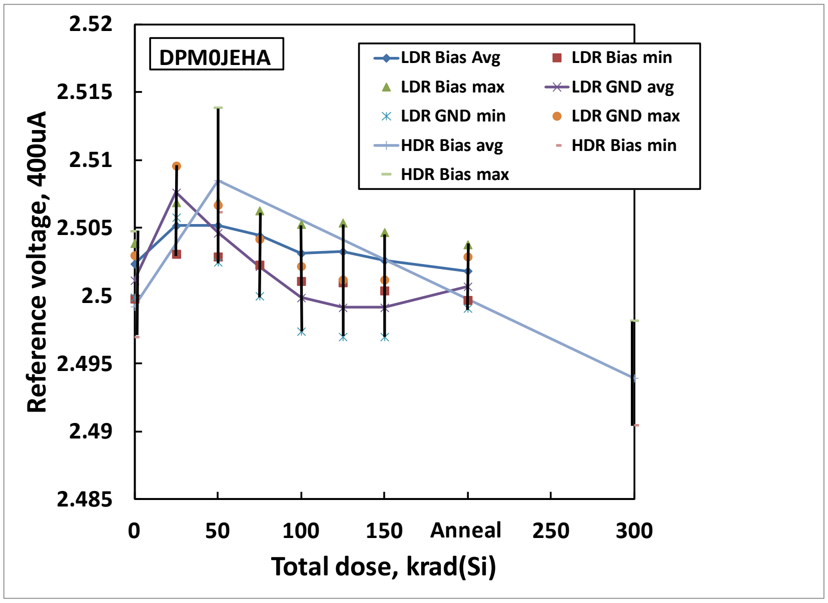


Fig. 3: IS-1009EH fab lot DPM0JEHA reference output voltage at 400uA as a function of total dose irradiation at low dose rate for the unbiased (all pins grounded) and the biased (per Fig. 1) cases and at high dose rate for the biased (also per Fig. 1) case. The low dose rate irradiations were followed by a biased anneal at 100^{o}C for 168 hours. The low dose rate was 0.01 rad(Si)/s and the high dose rate 65 rad(Si)/s. Sample size for each of the two low dose rate cells was 8 each, while the high dose rate cell had 19 samples. This is an informational parameter used to develop the load regulation (see Fig. 5) and is not specified in the SMD.

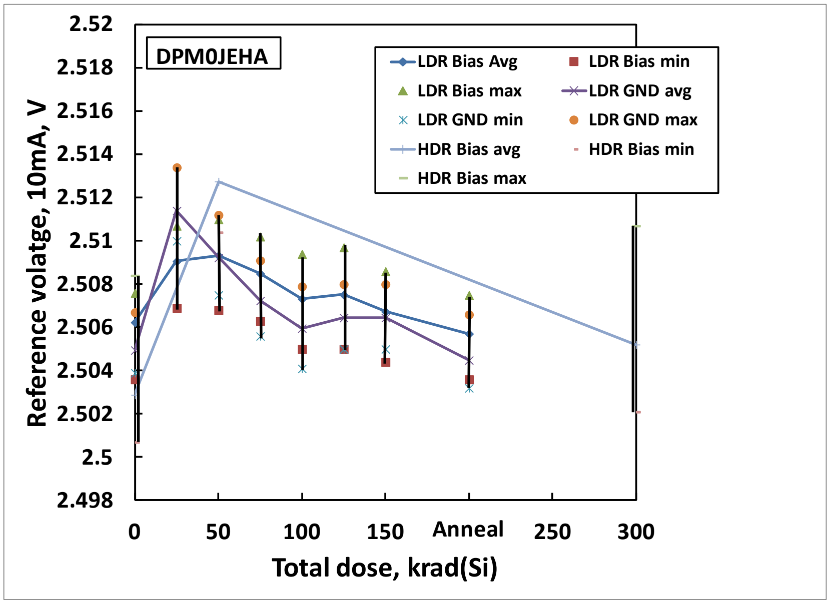


Fig. 4: IS-1009EH fab lot DPM0JEHA reference output voltage at 10mA as a function of total dose irradiation at low dose rate for the unbiased (all pins grounded) and the biased (per Fig. 1) cases and at high dose rate for the biased (also per Fig. 1) case. The low dose rate irradiations were followed by a biased anneal at 100^{o}C for 168 hours. The low dose rate was 0.01 rad(Si)/s and the high dose rate 65 rad(Si)/s. Sample size for each of the two low dose rate cells was 8 each, while the high dose rate cell had 19 samples. . This is an informational parameter used to develop the load regulation (see Fig. 5) and is not specified in the SMD.

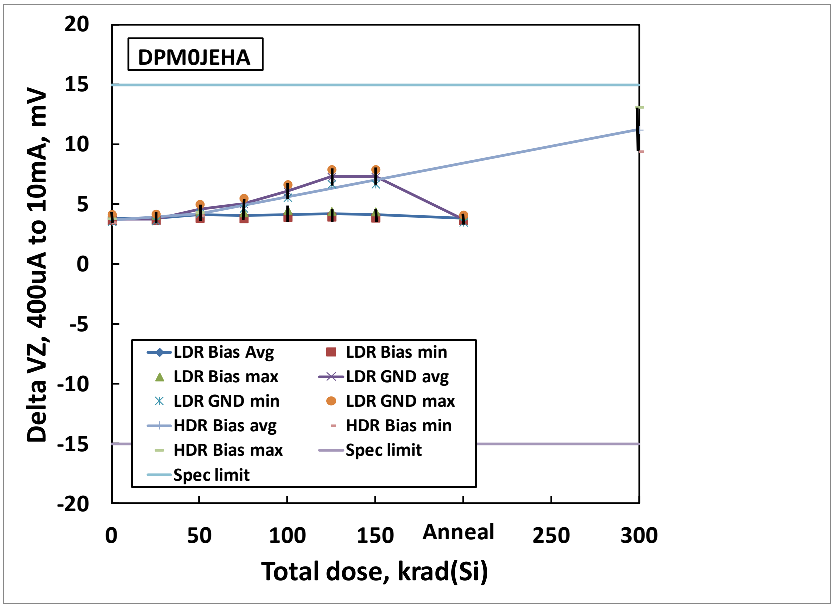


Fig. 5: IS-1009EH fab lot DPM0JEHA load regulation, 400uA to 10mA, as a function of total dose irradiation at low dose rate for the unbiased (all pins grounded) and the biased (per Fig. 1) cases and at high dose rate for the biased (also per Fig. 1) case. The low dose rate irradiations were followed by a biased anneal at 100^{o}C for 168 hours. The low dose rate was 0.01 rad(Si)/s and the high dose rate 65 rad(Si)/s. Sample size for each of the two low dose rate cells was 8 each, while the high dose rate cell had 19 samples. The post-irradiation SMD limits are -15.0mV to +15.0mV.

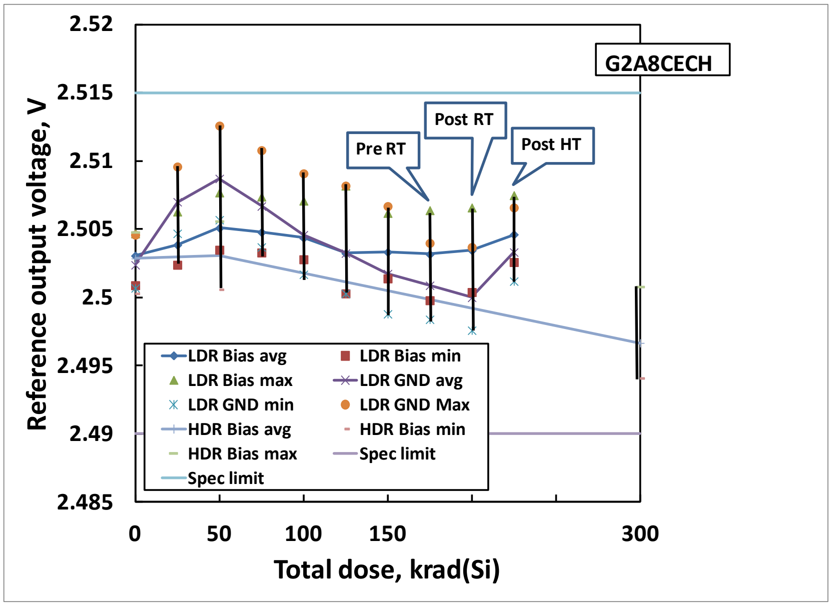


Fig. 6: IS-1009EH fab lot G2A8CECH reference output voltage at 1mA as a function of total dose irradiation at low dose rate for the unbiased (all pins grounded) and the biased (per Fig. 1) cases and at high dose rate for the biased (also per Fig. 1) case. The low dose rate irradiations were carried out to 150 krad(Si) and were followed (see text) by a biased anneal at 25°C for 24 hours and a further biased anneal at 100°C for 168 hours. The low dose rate was 0.01 rad(Si)/s and the high dose rate 65 rad(Si)/s. Sample size for each of the two low dose rate cells was 14 each, while the high dose rate cell had 28 samples. The post-irradiation SMD limits are 2.490V to 2.515V.

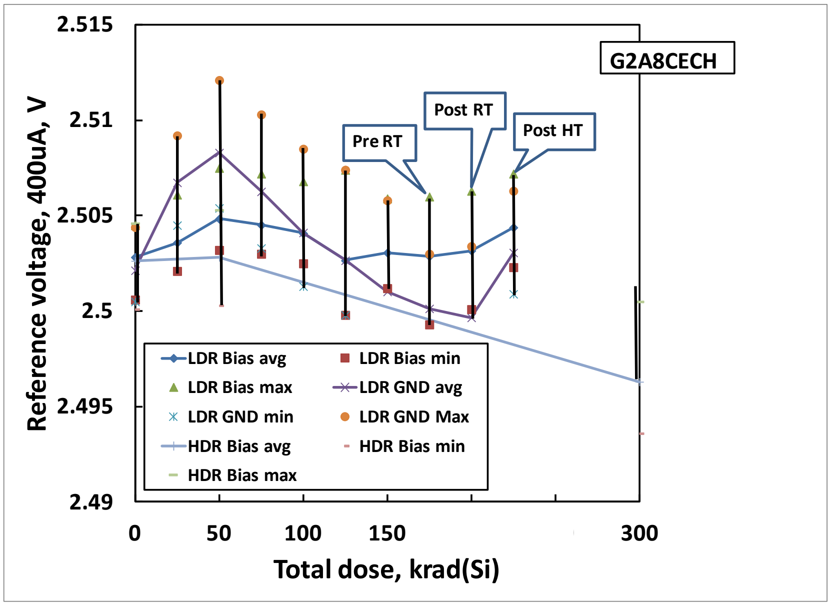


Fig. 7: IS-1009EH fab lot G2A8CECH reference output voltage at 400uA as a function of total dose irradiation at low dose rate for the unbiased (all pins grounded) and the biased (per Fig. 1) cases and at high dose rate for the biased (also per Fig. 1) case. The low dose rate irradiations were carried out to 150 krad(Si) and were followed (see text) by a biased anneal at 25°C for 24 hours and a further biased anneal at 100°C for 168 hours. The low dose rate was 0.01 rad(Si)/s and the high dose rate 65 rad(Si)/s. Sample size for each of the two low dose rate cells was 14 each, while the high dose rate cell had 28 samples. This is an informational parameter used to develop the load regulation (see Fig. 9) and is not specified in the SMD.

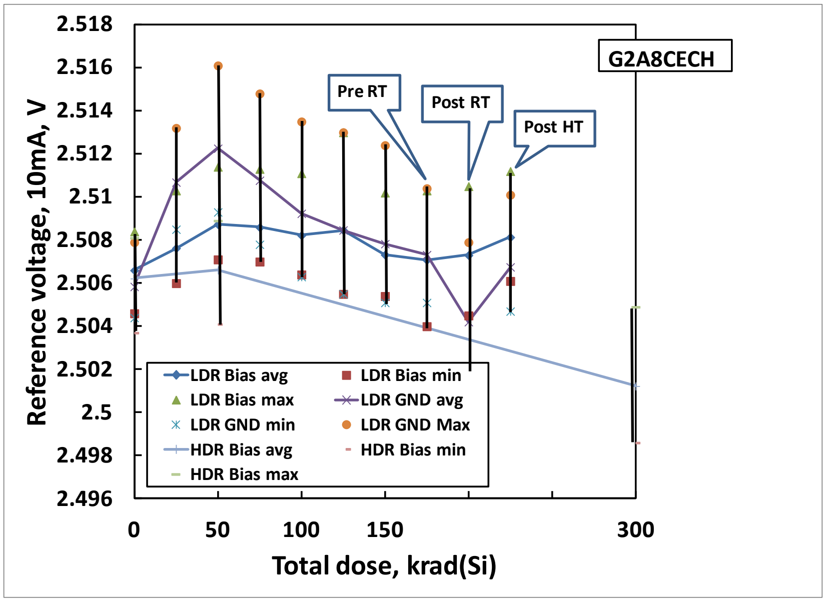


Fig. 8: IS-1009EH fab lot G2A8CECH reference output voltage at 10mA as a function of total dose irradiation at low dose rate for the unbiased (all pins grounded) and the biased (per Fig. 1) cases and at high dose rate for the biased (also per Fig. 1) case. The low dose rate irradiations were carried out to 150 krad(Si) and were followed (see text) by a biased anneal at 25°C for 24 hours and a further biased anneal at 100°C for 168 hours. The low dose rate was 0.01 rad(Si)/s and the high dose rate 65 rad(Si)/s. Sample size for each of the two low dose rate cells was 14 each, while the high dose rate cell had 28 samples. This is an informational parameter used to develop the load regulation (see Fig. 9) and is not specified in the SMD.

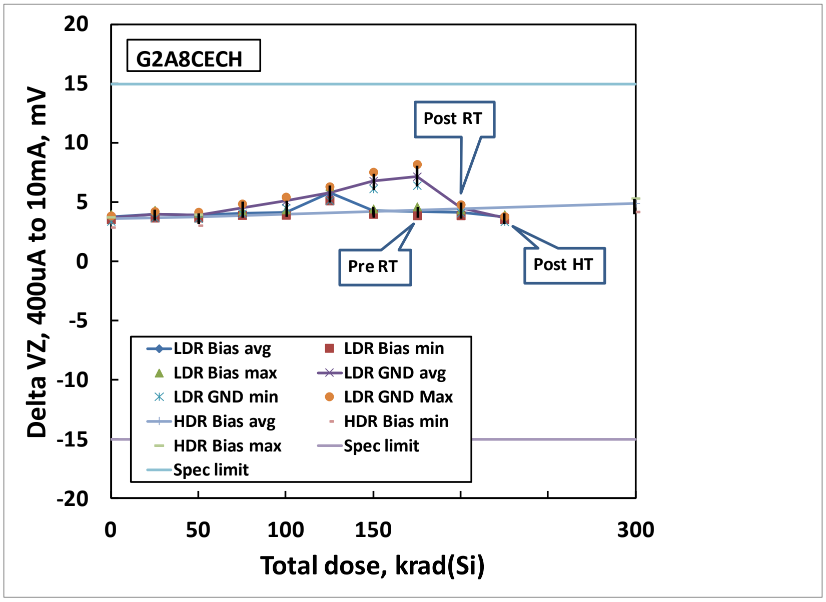


Fig. 9: IS-1009EH fab lot G2A8CECH load regulation, 400uA to 10mA, as a function of total dose irradiation at low dose rate for the unbiased (all pins grounded) and the biased (per Fig. 1) cases and at high dose rate for the biased (also per Fig. 1) case. The low dose rate irradiations were carried out to 150 krad(Si) and were followed (see text) by a biased anneal at 25°C for 24 hours and a further biased anneal at 100°C for 168 hours. The low dose rate was 0.01 rad(Si)/s and the high dose rate 65 rad(Si)/s. Sample size for each of the two low dose rate cells was 14 each, while the high dose rate cell had 28 samples. The post-irradiation SMD limits are -15.0mV to +15.0mV.

6: Discussion and conclusion

The present tests were undertaken to determine the response of current production parts to high and low dose rate irradiation and to evaluate the effects of the changed passivation system. A further objective was the evaluation of post low dose rate irradiation anneals. Testing at both dose rates of samples taken from two fabrication lots of the IS-1009EH is complete. All monitored parameters remained within the SMD post-irradiation specifications at all downpoints, see Tables 1 and 2.

Figs. 2 through 5 show the results for fab lot DPM0JEHA. The reference voltage at 1 mA (Fig. 2) is the key parameter and showed good stability over low dose irradiation and the subsequent HT anneal. The response curve shows an increase of the reference voltage to the 50 krad(Si) level, followed by a gradual decrease to the maximum dose of 150 krad(Si). The high dose rate response showed similar behaviour, although there were considerably fewer downpoints. The HT anneal had no effect other than tightening up the distribution somewhat.

Figs. 3 and 4 show the reference voltage at 400 µA and 10 mA; these parameters are not specified in the SMD but are used to develop the load regulation measurement of the part. Both parameters showed a similar response to the 1 mA case.

Fig. 5 shows the load regulation of the part. This is simply the difference between the reference voltage at 400 µA and 10 mA, and the parameter showed good stability. The biased high dose rate irradiation was worst case, an interesting response in an all-bipolar part.

Figs. 6 through 9 show the results for fab lot G2A8CECH. The reference voltage (Fig. 6) showed good stability over low dose irradiation and the subsequent LT and HT anneals. The response curve showed the same increase to the 50 krad(Si) level, followed by a gradual decrease to the maximum dose of 150 krad(Si). The high dose rate response showed similar behaviour. Again, the two anneals had no effect other than tightening up the distribution somewhat.

Figs. 7 and 8 show the reference voltage at 400 µA and 10 mA; both parameters showed a similar response to the 1 mA case.

Fig. 9 shows the load regulation of the part. The parameter showed good stability, and the biased high dose rate irradiation was again worst case.

The IS-1009EH is implemented in the Intersil EBHF process, which has historically used silicon nitride passivation. Passivation structure, composition and deposition process have been shown to strongly affect the hydrogen transport dynamics and hence the low and high dose rate response of the resulting parts. The EBHF process has recently been upgraded to single-layer Silox passivation identical to that used in the RSG process. The IS-1009EH uses silicon dioxide (‘silox’) passivation while the earlier IS-1009RH uses silicon nitride (‘nitride’) passivation. The present results are consistent, however, with the IS-1009EH data obtained earlier and reported [1] on the Intersil Web site. Both parts showed little, if any, low dose rate or bias sensitivity, with the low dose rate grounded condition marginally worst-case for some parameters.

The IS-1009EH is considered moderately low dose rate sensitive but remains well within the SMD post-irradiation limits to a maximum of 150 krad(Si) in this environment.

7: Appendices

7.1: Reported parameters.

Fig.	Parameter	SMD limit, low	SMD limit, high	Units	Fab lot	Notes
2	Reference voltage	2.490	2.515	V	DPM0JEHA	IZ = 1mA
3	Reference voltage	-	-	V	DPM0JEHA	IZ = 400µA
4	Reference voltage	-	-	V	DPM0JEHA	IZ = 10mA
5	Load regulation	-15	+15	mV	DPM0JEHA	IZ = 400µA to 10mA
6	Reference voltage	2.490	2.515	V	G2A8CECH	IZ = 1mA
7	Reference voltage	-	-	V	G2A8CECH	IZ = 400µA
8	Reference voltage	-	-	V	G2A8CECH	IZ = 10mA
9	Load regulation	-15	+15	mV	G2A8CECH	IZ = 400µA to 10mA

Note 1: Limits are taken from Standard Microcircuit Drawing (SMD) 5962-00523.
Note 2: Parameters shown in Figures 3, 4, 7 and 8 are for information only and are not specified in the SMD.

8: Document revision history

Revision	Date	Pages	Comments
0	January 2014	All	Original issue

9. References

[1] van Vonno, N. W., ‘Total dose testing of the IS-1009EH voltage reference’, January 2011, see http://www.intersil.com.