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Neutron testing of the IS1009RH voltage reference

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Revision 0

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1. Introduction

This report summarizes results of 1 MeV equivalent neutron testing of the IS1009RH voltage reference. The test was conducted in order to determine the sensitivity of the part to the displacement damage caused by the neutron environment. Neutron fluences ranged from 2 x 10^{12} n/cm^2 to 1 x 10^{14} n/cm^2 in an approximately logarithmic sequence. This project was carried out in collaboration with Honeywell Aerospace (Clearwater, FL), and their support is gratefully acknowledged.

2: Part Description

The IS-1009RH is a 2.5V radiation hardened shunt reference designed to provide a stable 2.5V reference over a wide current range. The device is designed to maintain stability over the full military temperature range and over time. 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 part's temperature coefficient. Constructed using the Intersil dielectrically isolated EBHF process, this device is immune to single event latchup (SEL) and has been specifically designed to provide highly reliable performance in harsh radiation environments. Specifications for Rad Hard QML devices are controlled by the Defense Logistics Agency (DLA) in Columbus, OH. Detailed electrical specifications for this device may be found in SMD 5962-00523. The IS1009RH is offered in a hermetic TO-206AB 'can' or in a SMD.5 hermetic surface mount package. The device operates over the standard military temperature range of -55°C to +125°C.

The IS1009RH is implemented in the EBHF process, which is a complementary bipolar flow using dielectrically isolated (DI) substrates. The process is used for a range of commercial and hardened operational amplifiers and voltage references. The DI technology enables vertical NPN and PNP devices, unlike the vertical NPN/lateral PNP combination used in commercial junction isolated processes. The vertical PNP device improves AC performance and total dose hardness, while the DI substrate eliminates latchup by either electrical or SEE conditions. The process is in volume production under MIL-PRF-38535 certification in the Palm Bay, Florida Intersil wafer fabrication facility.

3: Test Description

3.1 Irradiation Facilities

Neutron irradiation was performed by the Honeywell team at the Fast Burst Reactor facility at White Sands Missile Range (White Sands, NM), which provides a controlled 1MeV equivalent neutron flux. Parts were tested in an unbiased configuration with all leads open. As neutron irradiation activates many of the elements found in a packaged integrated circuit, the parts exposed at the higher neutron levels required (as expected) significant 'cooldown time' before being shipped back to Palm Bay for electrical testing.

3.2 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.

3.3 Experimental matrix

Testing proceeded in general accordance with the guidelines of MIL-STD-883 Test Method 1017. The experimental matrix consisted of five samples irradiated at 2×10^{12} n/cm^2, five samples irradiated at 1×10^{13} n/cm^2, five samples irradiated at 3×10^{13} n/cm^2 and five samples irradiated at 1×10^{14} n/cm^2. Two control units were used.

4: Results

4.1 Test results

Neutron testing of the IS1009RH is complete and the results are reported in the balance of this report. It should be realized when reviewing the data that each neutron irradiation was made on a different 5-unit sample; this is not total dose testing, where the damage is cumulative.

4.2 Variables data

The plots in Figs. 1 through 6 show data plots for key parameters before and after irradiation to each level. The plots show the average, minimum and maximum of each parameter as a function of neutron irradiation.

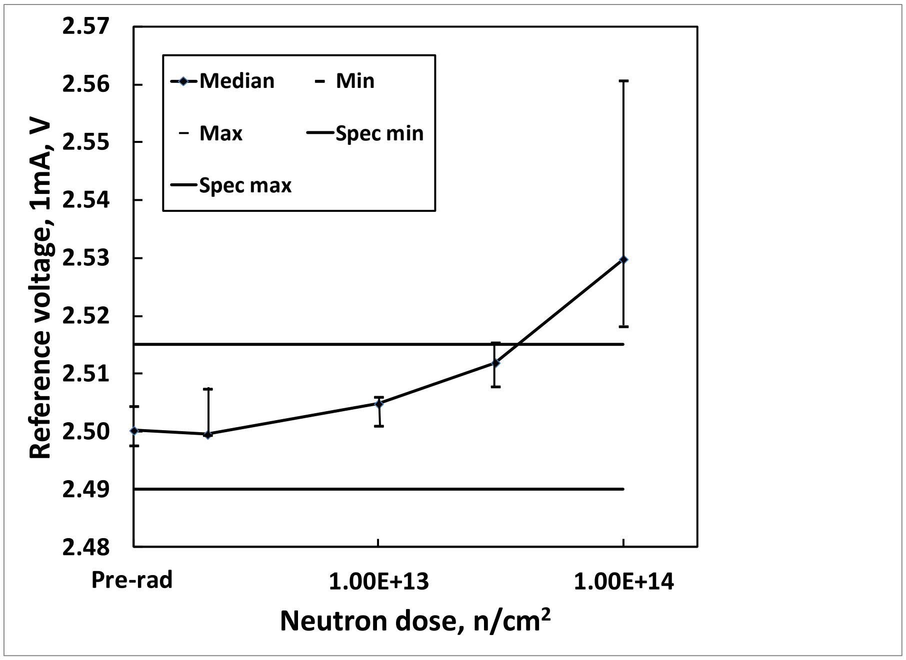

Fig. 1: IS1009RH reference voltage as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2, 3 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with two control units. The post-irradiation SMD limits are 2.490V to 2.515V.

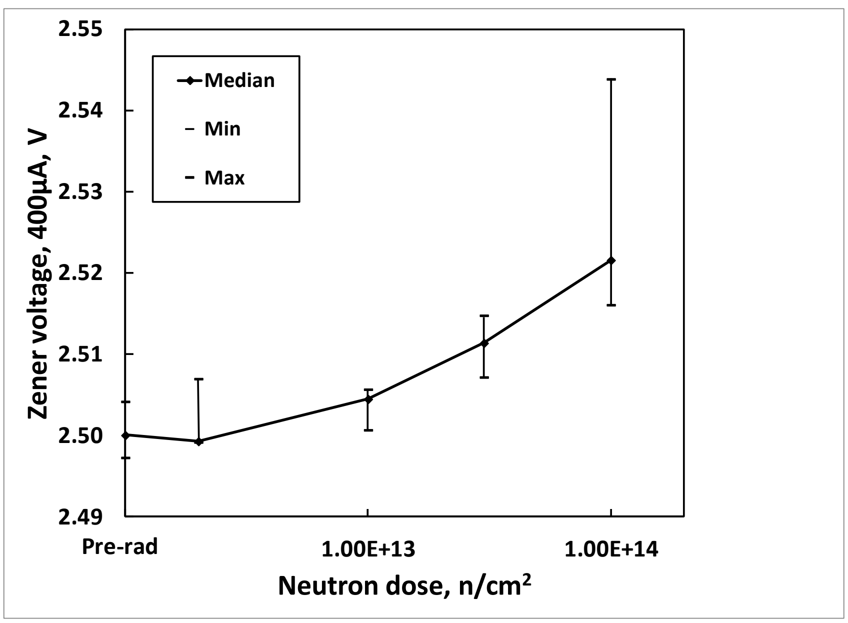

Fig. 2: IS1009RH Zener voltage at 400µA as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2, 3 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with two control units. This is an informational parameter used to develop the dVZ/dI parameter (Fig. 4) and is not specified in the SMD.

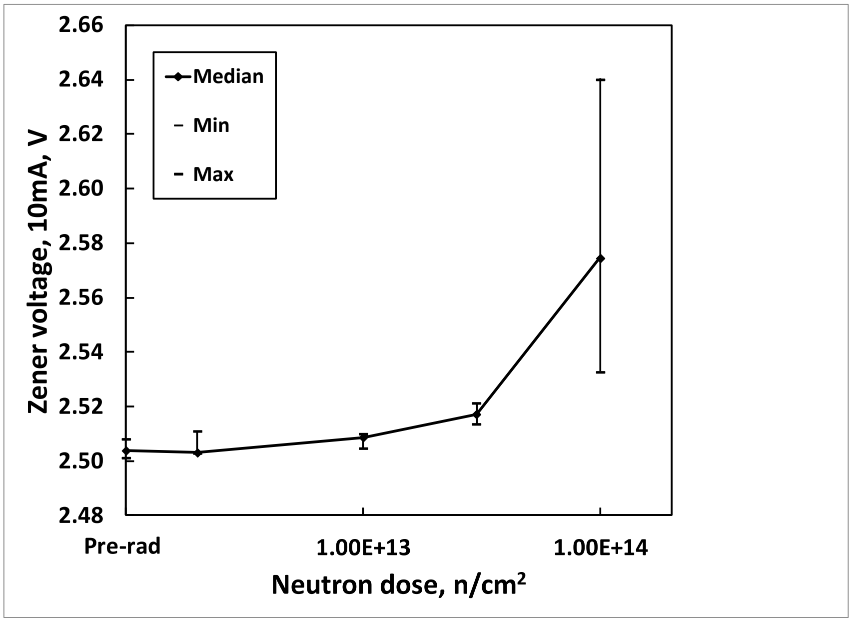

Fig. 3: IS1009RH Zener voltage at 10mA as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2, 3 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with two control units. This is an informational parameter used to develop the dVZ/dI parameter (Fig. 4) and is not specified in the SMD.

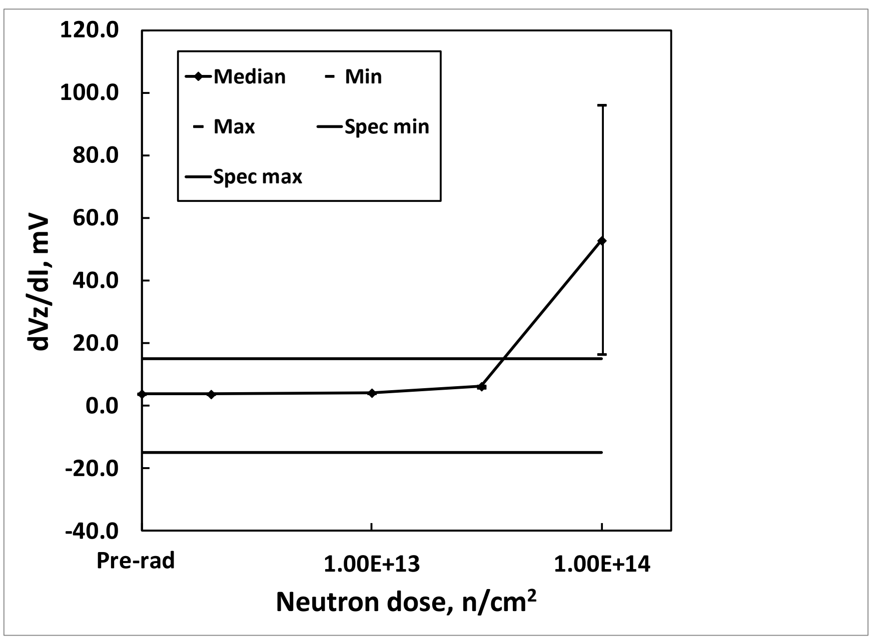

Fig. 4: IS1009RH change in Zener voltage over change in Zener current, current range 400µA to 10mA, as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2, 3 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2), with two control units. The post-irradiation SMD limits are -15.0mV to 15.0mV.

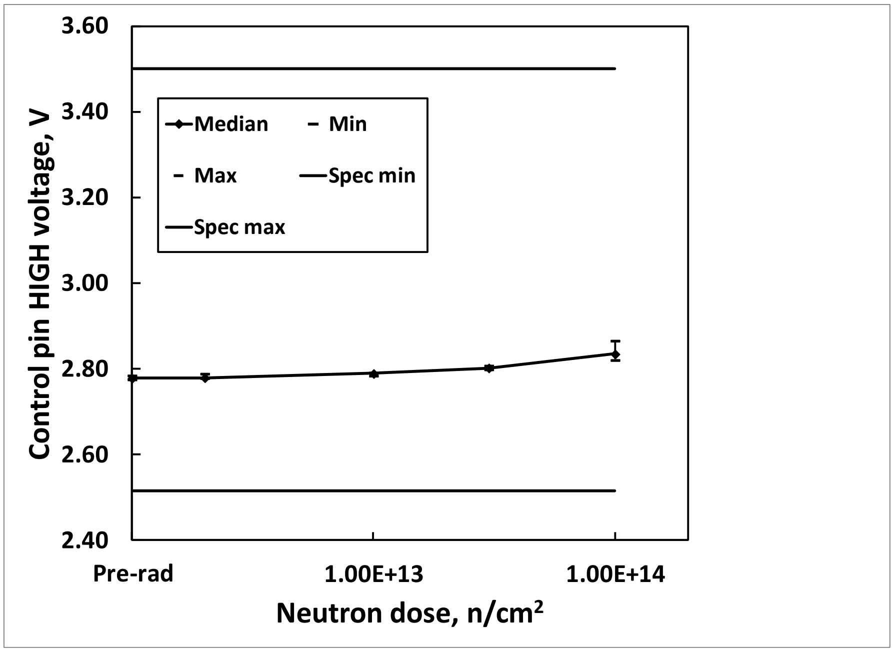

Fig. 5: IS1009RH control pin HIGH voltage as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (2×10^{12} n/cm^2, 1×10^{13} n/cm^2, 3×10^{13} n/cm^2 and 1×10^{14} n/cm^2), with two control units. This is an informational parameter and is not specified in the SMD.

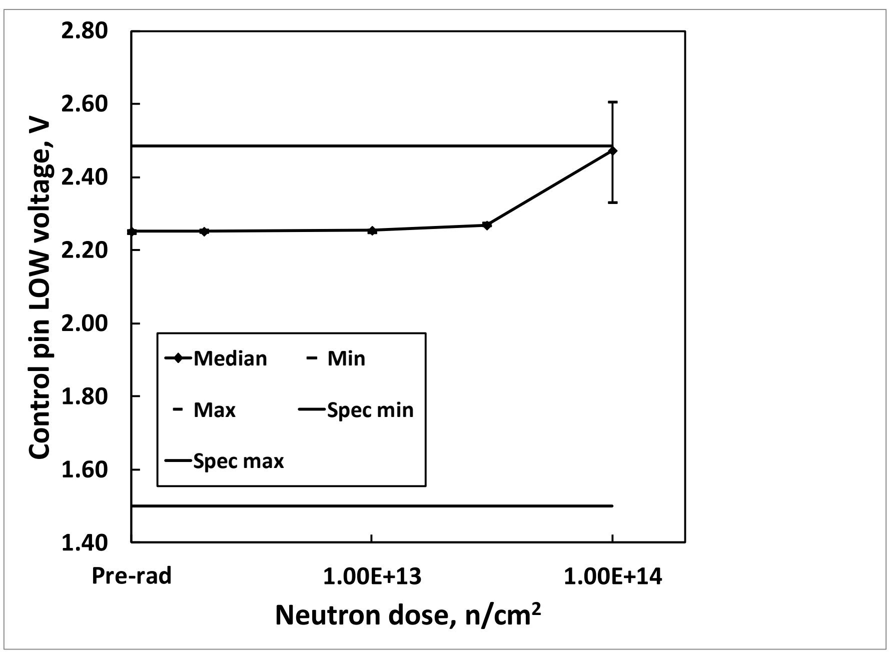

Fig. 6: IS1009RH control pin LOW voltage as a function of neutron irradiation, showing the mean, minimum and maximum of the populations at each level. Sample size was 5 for each cell (2×10^{12} n/cm^2, 1×10^{13} n/cm^2, 3×10^{13} n/cm^2 and 1×10^{14} n/cm^2), with two control units. This is an informational parameter and is not specified in the SMD.

5: Discussion and conclusion

This document reports the results of neutron testing of the IS1009RH shunt voltage reference. Samples were irradiated to levels of 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2, 3 x 10^{13} n/cm^2 and 1 x 10^{14} n/cm^2 with a sample size of five parts per cell. It should again be realized when reviewing the data that each neutron irradiation was made on a different 5-unit sample; this is not total dose testing, where the damage is cumulative. ATE characterization testing was performed before and after the irradiations, and two control units were used to insure repeatable data. Variables data for monitored parameters is presented in Figs. 1 through 6. We will discuss the results on a parameter by parameter basis. The 2 x 10^{12} n/cm^2 level is of some interest in the context of recent developments in the JEDEC community, where the discrete component vendor community have signed up for characterization testing (but not for acceptance testing) at this level.

The IS1009RH is not formally designed for neutron hardness. The part is built in a DI complementary bipolar process. These bipolar transistors are minority carrier devices, obviously, and may be expected to be sensitive to displacement damage (DD) at the higher levels. This expectation turned out to be correct. We will discuss the results on a parameter by parameter basis and then draw some conclusions. This is a simple device and only six parameters are monitored, two of which are actually specified in the SMD.

The reference voltage is the key parameter for this part. It showed good stability after 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 3 x 10^{13} n/cm^2 irradiation but was out of specification after 1 x 10^{14} n/cm^2 irradiation. The range was also greatly increased at this highest level.

The Zener voltage at both 400µA and 10mA showed good stability after 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 3 x 10^{13} n/cm^2 irradiation but increased significantly after 1 x 10^{14} n/cm^2 irradiation. The range was also greatly increased at this highest level. These are informational parameters and are not specified in the SMD.

The Zener voltage change over a range of Zener currents (measured from 400µA to 10mA) showed good stability after 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 3 x 10^{13} n/cm^2 irradiation but was out of specification after 1 x 10^{14} n/cm^2 irradiation. The range was also greatly increased at this highest level. This is the second parameter specified in the SMD.

The Adjust pin HIGH and LOW voltages showed good stability after 2 x 10^{12} n/cm^2, 1 x 10^{13} n/cm^2 and 3 x 10^{13} n/cm^2 irradiation. The LOW voltage increased significantly after 1 x 10^{14} n/cm^2 irradiation. These are informational parameters and are not specified in the SMD.

We conclude that the IS1009RH is capable of post 3 x 10^{13} n/cm^2 operation within the SMD post-total dose parameters. The part is not capable of post 1 x 10^{14} n/cm^2 operation as several parameters changed drastically; the part did, however, remain functional.

6: Appendices

6.1: Reported parameters.

Fig.	Parameter	Limit, low	Limit, high	Units	Notes
1	Reference voltage	2.490	2.515	V	
2	Zener voltage, 400µA	-	-	-	
3	Zener voltage, 10mA	-	-	-	
4	dVZ/dIZ	-15.0	15.0	mV	
5	Control pin HIGH voltage	-	-	-	
6	Control pin LOW voltage	-	-	-	-

7: Document revision history

Revision	Date	Pages	Comments
0	13 June 2013	All	Original issue