



Low Dose Rate Testing of the Intersil IS1009RH Hardened Voltage Reference

December 2006
Nick van Vonno
Intersil Corporation

Abstract:

This document provides a brief introduction to low dose rate effects including discussion of Intersil's approach to testing and qualification issues. We then report results of baseline 100krad(Si) low dose rate testing of the Intersil IS1009RH Hardened Voltage Reference.

Table of Contents:

- 1: Introduction: What is Low Dose Rate Sensitivity?
- 2: Low Dose Rate Testing Strategy at Intersil
- 3: Low Dose Rate Testing of the Intersil IS1009RH Hardened Voltage Reference
- 4: Conclusion
- 5: References

1: Introduction: What is Low Dose Rate Sensitivity?

Low dose rate effects have been a topic of considerable research interest for the last fifteen years. The first section of this report will supply a brief technical introduction to the topic.

Total ionizing dose testing of semiconductor components has historically been performed at 'qualification' dose rates in the 50 – 300rad(Si)/s range as specified in MIL-STD-883. At 50rad(Si)/s, the low end of the dose rate specification range, a lot qualification test to a 300krad(Si) total dose specification takes a maximum of 1.67 hours, enabling the test to be carried out in less than a day. Intersil has historically performed total dose qualification testing of their hardened parts on a wafer by wafer basis, using Gammacell 220™ irradiators; the dose rate of our current Gammacell is approximately 130rad(Si)/s, and the 300krad(Si) test takes 38 minutes.

In the 1992 – 1993 time frame, researchers at Mission Research and Aerospace Corporation noted a surprising dose rate dependence in the total dose response of bipolar analog integrated circuits. Devices such as the industry-standard LM139 comparator showed severe degradation of such parameters as input bias current and input offset voltage when irradiated at very low dose rates. This enhanced low dose rate sensitivity (ELDRS) was subsequently observed in a broad range of bipolar and BiCMOS parts, but has not been seen in MOS parts (except in a very few unconfirmed cases in discrete MOS devices). In MOS parts the effects of low dose rate are opposite to those observed in bipolars; the damage anneals out at a constant rate, so lower dose rate testing causes less degradation, which is a much more intuitive result. Figure 1 shows a well-known if somewhat extreme sample response curve [1] for a bipolar operational amplifier.

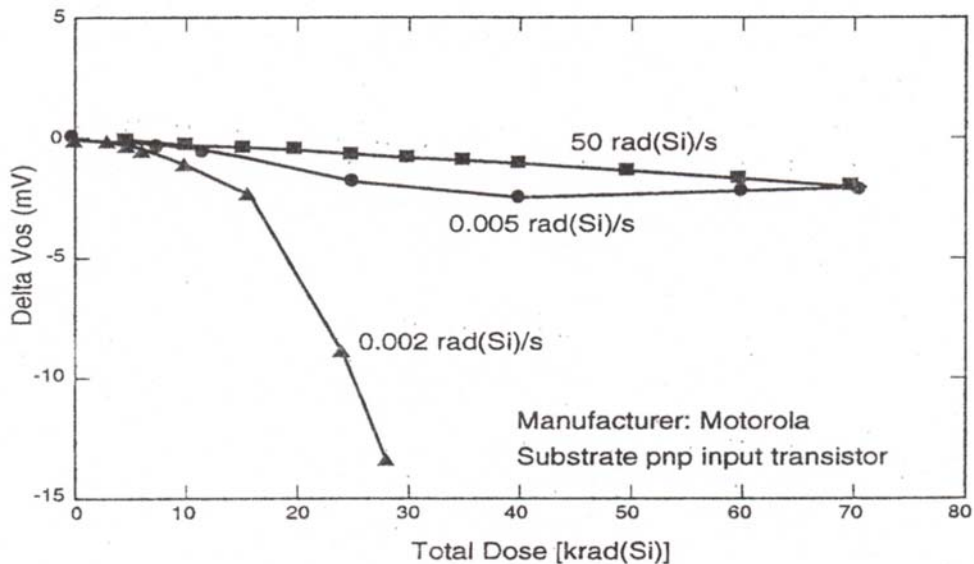


Figure 1: *Where is the bottom?* Degradation of the input offset voltage as a function of total dose of the Motorola LM324 operational amplifier at three dose rates [1]. Note that the input offset voltage shows excellent stability at the 50rad(Si)/s and .005rad(Si)/s dose rates, but degrades rapidly at the very low .002rad(Si)/s dose rate.

Following the initial findings in 1992, low dose rate sensitivity developed into one of the premier research topics in the radiation effects community, as evidenced by a large number of journal papers. Compendia of low dose rate results for a broad range of commercially available parts are particularly useful; these compendia [2] and other papers on the subject can be found in the IEEE Radiation Effects Data Workshop Record, which is published yearly and contains papers presented at the Workshop. The December issue of the IEEE Transactions on Nuclear Science serves as the proceedings of the IEEE Nuclear and Space Radiation Effects Conference (NSREC) and is another excellent source of technical information on low dose rate effects.

There has been significant work on identifying a basic mechanism that explains this effect, with mixed success. The theories relate to trapping and detrapping rates in the IC's dielectric thin film layers. A detailed discussion of the basic mechanisms of ELDRS is outside the scope of this document.

Intersil uses dielectrically isolated (DI) fabrication processes for its hardened analog parts. This eliminates latchup, either electrically or single-event caused, and also enables the use of a vertical PNP bipolar transistor of enhanced electrical performance as compared to lateral devices. Intersil expected these DI parts to show reduced sensitivity to low dose rate due to the vertical PNP structures used. The basis of this claim was the known softness of the lateral or substrate PNP transistors encountered in nearly all commercial junction-isolated (JI) processes. Radiation tests performed for device modeling work had shown the Intersil vertical devices to be much harder than laterals at qualification dose rates in the 50 – 300rad(Si)/s range, and it was expected that the low dose rate response of the vertical PNP device would track its response at high dose rate.

Workers outside and inside Intersil have verified this assumption. In 1999 researchers at NAVSEA/Crane published a paper [3] reporting positive results for the HS9-139RH quad comparator, which was found to be within its post-radiation parametric

limits after 300krad(Si) at .01rad(Si)/s. Baseline 100krad(Si) low dose rate testing of the HS9-139RH quad comparator and HS9S-117RH positive linear voltage regulator at Intersil is complete [4] and showed similarly positive results. A baseline test on the IS1009RH is now complete and the balance of this document reports the results of this test.

2: Low Dose Rate Testing Strategy at Intersil

In Intersil's approach, the standard MIL-STD-883 Method 1019.7 high dose rate wafer by wafer qualification testing will be supplemented by baseline low dose rate characterization testing on a part-by-part basis.

To this end Intersil has procured a J. L. Shepherd and Associates model 484 low dose rate ⁶⁰Co irradiator. This equipment is capable of dose rates of .01rad(Si)/s and is now on line in Intersil's Palm Bay, Florida facility. Appropriate fixturing to perform these tests in accordance with the requirements of MIL-STD-883 Method 1019.7 has been constructed and installed. All testing is performed under bias. The fixturing uses the same test boards as the Intersil high dose rate Gammacell 220 TM facility; the test configuration and bias voltages are the same as well, insuring a valid comparison between the results of low and high dose rate testing. During irradiation the devices under test are enclosed in a PbAl box, as specified by MIL-STD-883 Method 1019.7. in order to filter out low-energy photons caused by backscattering effects. We use Far West Technology, Inc. (Goleta, CA) model FWT-70 Opti-Chromic radiochromic dosimeters to monitor accumulated dose. Test samples are taken from burned-in production part inventory, as burnin and its attendant heat treats have been shown [5] to play a role in low dose rate response.

3: Low Dose Rate Testing of the Intersil IS1009RH Hardened Voltage Reference

The IS1009RH is a 2.5V shunt-mode voltage regulator designed to provide a stable 2.5V reference output voltage. The device is stable over a wide current range and is designed to maintain that 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 of the reference.

The part is constructed using the Intersil dielectrically isolated, complementary bipolar EBHF process. The process uses silicon nitride passivation. It is immune to single-event latchup and has been specifically designed to provide reliable performance in harsh radiation environments. Single-event effects (SEE) characterization testing of the part has been performed and a summary [6] of results can be found on the Intersil homepage.

The Defense Supply Center (DSCC) in Columbus, OH controls Standard Microcircuit Drawings (SMD) for radiation-hardened QML devices. Detailed electrical specifications for these devices are contained in SMD 5962-00523. A "hot-link" is provided on the Intersil homepage for downloading the applicable SMD, see www.intersil.com/spacedefense/space.htm

Key features of the IS-1009RH are listed below.

- Electrically Screened to SMD # 5962-00523
- QML qualified per MIL-PRF-38535 requirements
- Radiation hardened:
 - Total Dose 300 krad(Si)
 - Latch-up Immune, dielectrically isolated process
 - Characterized SEE response
- Reverse breakdown voltage (V_Z): 2.5V
- Change in V_Z vs. output current (400 μ A to 10mA): 6mV
- Change in V_Z vs. temperature (-55°C to 125°C): 15mV
- Maximum reverse breakdown current: 20mA
- Device is tested with 10 μ F bypass capacitance connected from V+ to V-, which provides optimum stability
- Interchangeable with industry standard 1009 and 136 types

A baseline 100krad(Si) low dose rate test of the Intersil IS-1009RH Hardened Voltage Reference is complete. This test had intermediate down points of 10krad(Si) and 25krad(Si). Samples were irradiated at a dose rate of 10 millirad(Si)/s using the J. L. Shepherd and Associates model 484 low dose rate irradiator. The sample size for this test was 12, and the parts were irradiated per MIL-STD-883 Method 1019.7 using the irradiation bias configuration specified in SMD 5962-00523 (see Figure 2, below). This irradiation bias is used to permit a more direct comparison between low and high dose rate results. Note also that the 'all pins grounded' configuration is not always worst case, and internal (unpublished) Intersil data has shown biased irradiation to be in fact worst-case for some RSG parts. Downpoint testing was performed using the standard automated test equipment (ATE) procedure used for production testing.

Samples were drawn from burned-in standard production material, as indicated above, and were packaged in the TO-206AB hermetically sealed 'can' package. The pre-irradiation, 10krad(Si), 25krad(Si) and 100krad(Si) results are summarized in Figures 3 and 4, below.

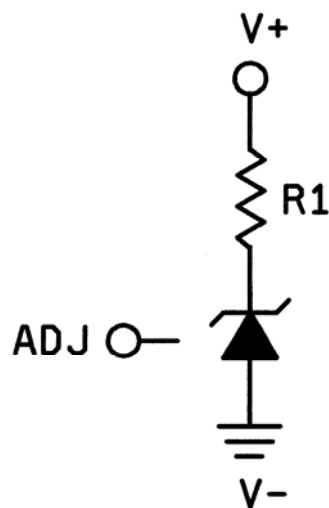


Figure 2: IS1009RH irradiation bias configuration per SMD 5962-00523. Applied voltage is 5VDC +/- .5V, adjust pin is open and R1 is 2.5K +/-5%.

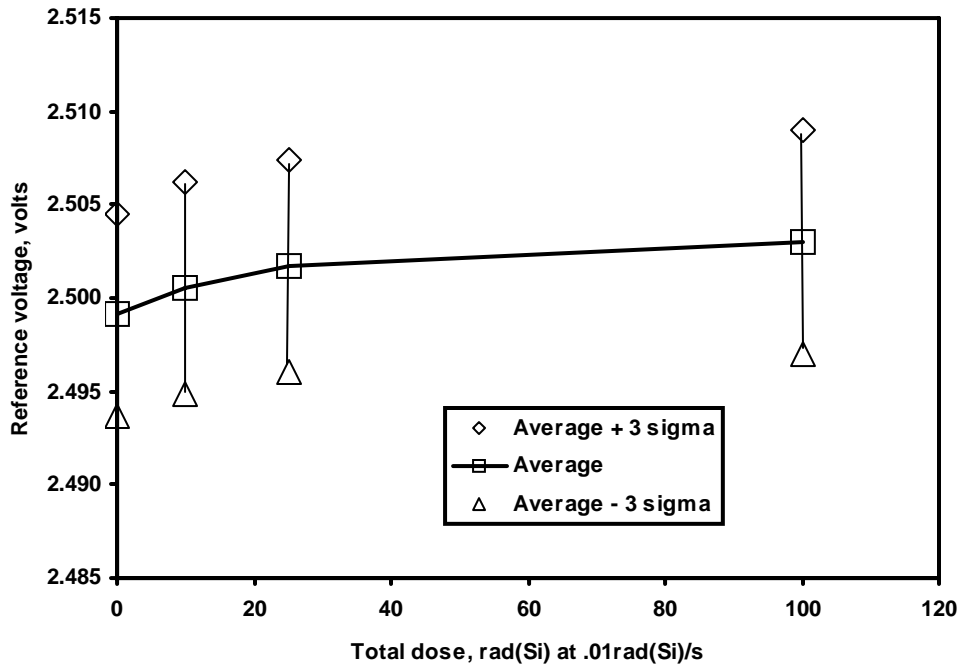


Figure 3: IS1009RH reference output voltage at 1 mA load current as a function of total dose. Sample size is 12 parts. The maximum post-radiation output voltage range is 2.485 – 2.515 volts.

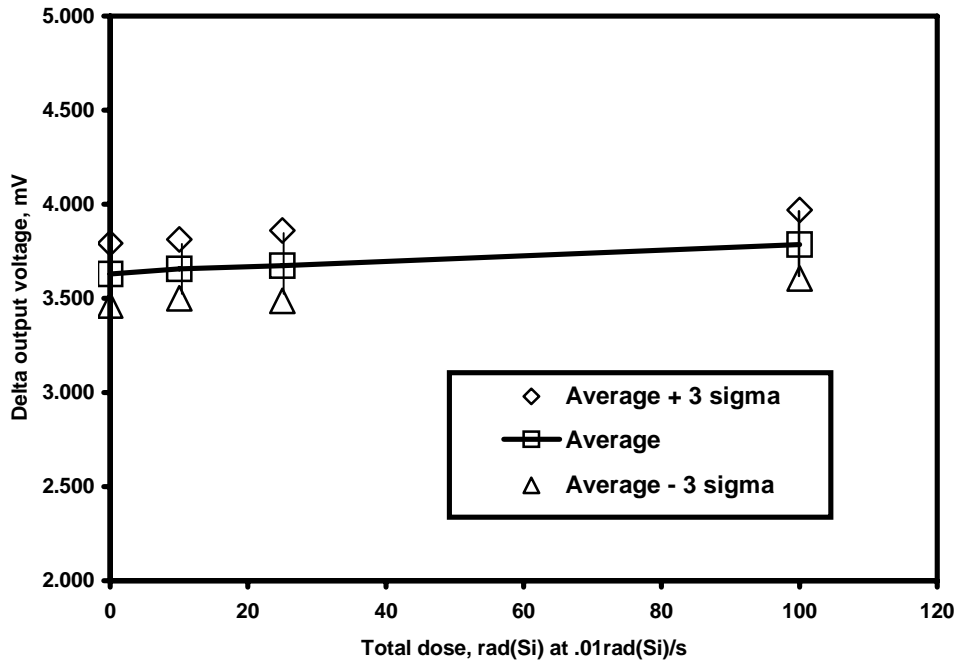


Figure 4: IS1009RH change in reference voltage vs. output current (400uA to 10mA), as a function of total dose. Sample size is 12 parts. The maximum post-radiation change in reference voltage range is +/- 15mV.

The IS1009RH is built in the Intersil EBHF process, which has been shown to have moderate ELDRS sensitivity. The 100krad(Si) data shows approximately three millivolts shift in the reference output voltage, with no increase in the standard deviation.

All parts remained well within the 2.485 – 2.515-volt post-radiation specification. The change in reference voltage vs. output current offset also showed excellent stability. None of the 12 parts tested failed any of the post-radiation SMD limits. We conclude that the IS1009RH shows little low dose rate sensitivity up to a level of 100krad(Si).

4: Conclusion

This document provides technical background, test conditions, data and conclusions of a low dose rate test of the IS1009RH Hardened Voltage Reference performed at Intersil Corporation. The IS1009RH showed little dose rate sensitivity after 100krad(Si) low dose rate irradiation.

5: References

[1] A.H. Johnston, C.I. Lee and B. G. Rax, 'Enhanced Damage in Bipolar Devices at Low Dose Rates: Effects at Very Low Dose Rates', *IEEE Transactions on Nuclear Science*, December 2002.

[2] R. L. Pease, S. S. McClure, A. H. Johnston, J. Gorelick, T. L. Turflinger, M. Gehlhausen, J. Krieg, T. Carriere and M. R. Shaneyfelt, 'An Update Data Compendium of Enhanced Low Dose Sensitive (ELDRS) Bipolar Linear Circuits', *IEEE 2001 Radiation Effects Data Workshop Record*, July 2001.

[3] J. F. Krieg, J. L. Titus, D. Emily, M. Gehlhausen, J. W. Swonger and D. C. Platteter, 'Enhanced Low Dose Rate Sensitivity (ELDRS) in a Voltage Comparator which only Utilizes Complementary Vertical NPN and PNP Transistors', *IEEE Transactions on Nuclear Science*, December 1999.

[4] http://www.intersil.com/military/ELDRS_Test_Report.asp

[5] M. R. Shaneyfelt et al., 'Elimination of Enhanced Low-Dose-Rate Sensitivity and Thermal Stress Effects in Linear Bipolar Devices', *IEEE Transactions on Nuclear Science*, December 2002.

[6] http://www.intersil.com/military/SEE_Test_Report.asp

Document generated December 2006

Nick van Vonno

Intersil Corporation