National Aeronautics and Space Administration

HSYE-117RH Voltage Linear Regulator Total Ionizing Dose Test Report

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1. INTRODUCTION

The purpose of this test was to validate the Intersil HSYE-117RH-Q flight lot for use in the fabrication of Europa Clipper Propulsion subsystem flight hardware. This test shall serve as the radiation lot acceptance test (RLAT) for the flight lot date with wafer lot number G3X3CQC and lot date code (LDC) 1830. Low dose rate (LDR) irradiations have been performed by the manufacturer, but only to 100 krad(Si). This test determined the enhanced low dose rate sensitivity (ELDRS) of the device up to the mission specific dose of 125 krad(Si).

2. DEVICES TESTED

2.1. Part Background

The HSYE-117RH is an adjustable positive voltage linear regulator capable of operating with input voltages up to 40 V_{DC}. The output voltage is adjustable from 1.25 V to 37 V with two external resistors, and the device is capable of sourcing from 5 mA to 1.25 A max.

2.2. Device Under Test (DUT) Information

Eleven (11) parts from the flight lot of HSYE-117RHs were provided by the Europa Clipper Propulsion system to Code 561 for TID testing. One of the eleven was used as a control. All specifications and descriptions are according to the Intersil datasheet FN4560 Rev 10.00 March 25, 2014. More information can be found in Table 1.

Table 1. Part Identification Information

Part Number	HSYE-117RH-Q
REAG ID#	19-007
Manufacturer	Intersil
Lot Date Code	1830
Wafer Lot	G3X3CQC
Quantity Tested	11
Part Function	Voltage Linear Reference
Part Technology	Bipolar
Package	3-Pad Ceramic Leadless Chip Carrier (CLCC) – SMD.5

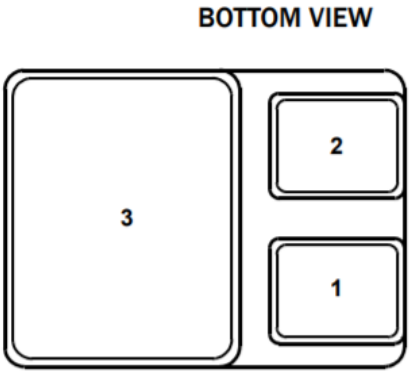

Fig. 1. Pinout of HSYE-117RH.

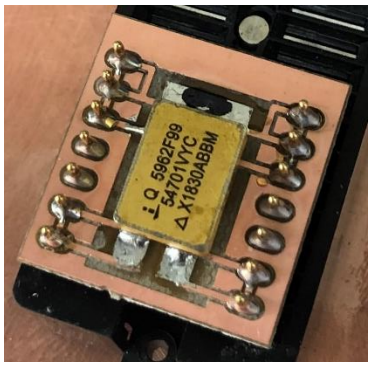
Fig. 2. Picture of HSYE-117RH.

3. TEST SETUP

The HSYE-117RH was soldered to a custom copper daughter card then inserted into a ZIF socket. The ZIF socket was on the test board. Two Keithley 2425s and one HP 34401A voltmeter were used to characterize the HSYE117's parameters.

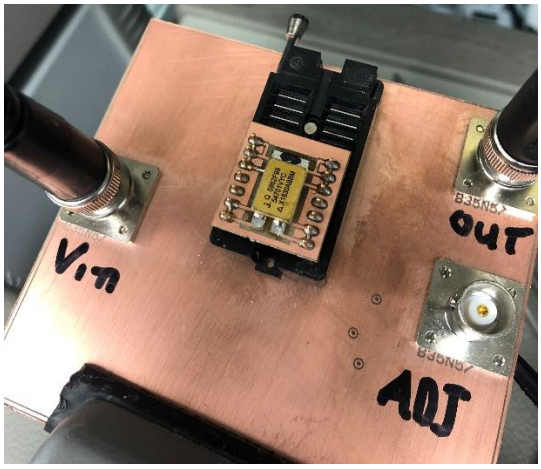

Fig. 3. Picture of DUT on test board

General test procedures were in accordance with MIL-STD-883, Method 1019, Condition D. Parts were serialized randomly. ESD procedures were followed during test and transfer of the devices between irradiation chamber and characterization. Exposures were performed at ambient laboratory temperature.

4. TEST DESCRIPTION

4.1 Irradiation Conditions

Radiation testing was done by exposing the parts to gamma radiation at a low dose rate. Twenty-four (24) parts were tested, twenty-two (22) exposed to radiation and one as a control. Prior to the first radiation dose, all twenty-four parts were electrically tested. After each exposure level, the parts were tested again and returned to radiation within the time limits defined by MIL-STD-883, Method 1019. Eleven (11) parts were biased and eleven (11) were unbiased during the irradiation steps. See Table 2 for more information.

Table 2. Device Grouping

Group	Qty	Bias	Dose Rate	Exposure Level Steps (krad(Si))
1	11	Unbiased	10 mrad(Si)/s	0, 25, 50, 75, 100, 125
2	11	Biased	10 mrad(Si)/s	0, 25, 50, 75, 100, 125
3	2	Control	N/A	N/A

The biased parts were placed in ZIF socket adapters on a wire wrapped board. During irradiation, DUTs were powered to +36 V. Table 3 describes the exact pinout of a biased part.

Table 3. Biased DUT pinout

Pin Name	Symbol	Pin Number	Expected Voltage and Current	Connection
Voltage Adjust Feedback Input	ADJUST	1	V_{ADJ} = 10.76 V I_{ADJ} = 64 µA	2.7 kΩ resistor to GND and 320 Ω resistor to V_{OUT}
Regulator Input	IN	2	V_{IN} = 36 V I_{IN} = 20.8 mA	+36 V
Regulator Output	OUT	3	V_{OUT} = 12.02 V I_{OUT} = 20.7 mA	320 Ω resistor to ADJUST and 715 Ω resistor to GND

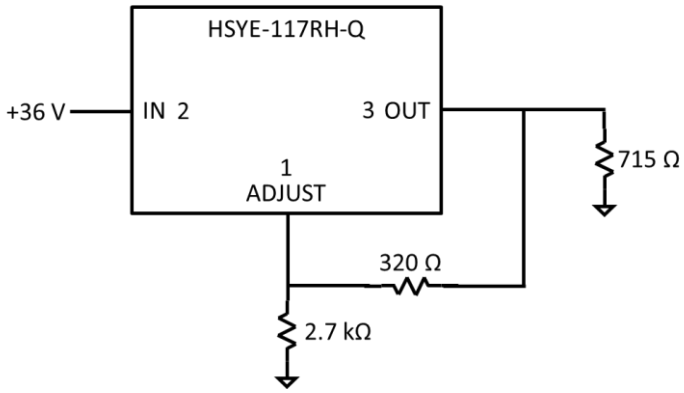

Fig. 4. Schematic of bias circuit for HSYE117RH voltage regulator.

4.2 Electrical Tests

Specification thresholds were set in accordance with the Intersil datasheet FN4560 Rev 10.00 March 25, 2014.

All data from the DC electrical tests in
Table 4 were logged in excel spreadsheet files. Data for all parts were measured and logged.

Table 4. List of Electrical Tests Performed

Test	Symbol	Conditions T_A = +25°C V_{DIFF} = 3 V	Specifications		
			Min	Typ	Max
Reference Voltage	V_{REF}	V_{DIFF} = 3 V V_{DIFF} = 40 V 5.0 mA ≤ I_{OUT} ≤ 5.5 mA	1.20 V	1.255 V	1.30 V
Line Regulation	R_{LINE}	$V_{REF} = V_{OUT} – V_{ADJ}$ 3 V ≤ V_{DIFF} ≤ 40 V 5.0 mA ≤ I_{OUT} ≤ 5.5 mA	-0.02%	0.005%	0.02%
Load Regulation	R_{LOAD}	V_{DIFF} = 3 V 5 mA ≤ I_{OUT} ≤ 1.25 A	-1.5%	-0.1%	1.5%
Adjust Pin Current	I_{ADJ}	V_{DIFF} = 3 V V_{DIFF} = 40 V 5.0 mA ≤ I_{OUT} ≤ 5.5 mA		64 µA	100 µA

5. Failure Criteria

The parameter limits are defined as those listed in the HSYE117RH datasheet.

6. Source Requirements

The total dose source is in a room air source gamma ray facility, which is compliant with MIL-STD-883, Method 1019. Dosimetry is NIST traceable.

7. Results

Reference Voltage and Adjust Pin Current thresholds were not exceeded during any of the irradiation steps. Both Line and Load Regulation parameters increased above the maximum specification after 75 krad(Si). Line regulation began degrading immediately. Load regulation remained essentially unchanged to the 75 krad(Si) measurement. At 100 krad(Si), load regulation measured above the maximum specification. After the 125 krad(Si) measurements, the load regulation was remeasured with smaller loads. Those measurements are shown as separate datapoints on that graph. All results, in graphical form and raw table form, are shown below.

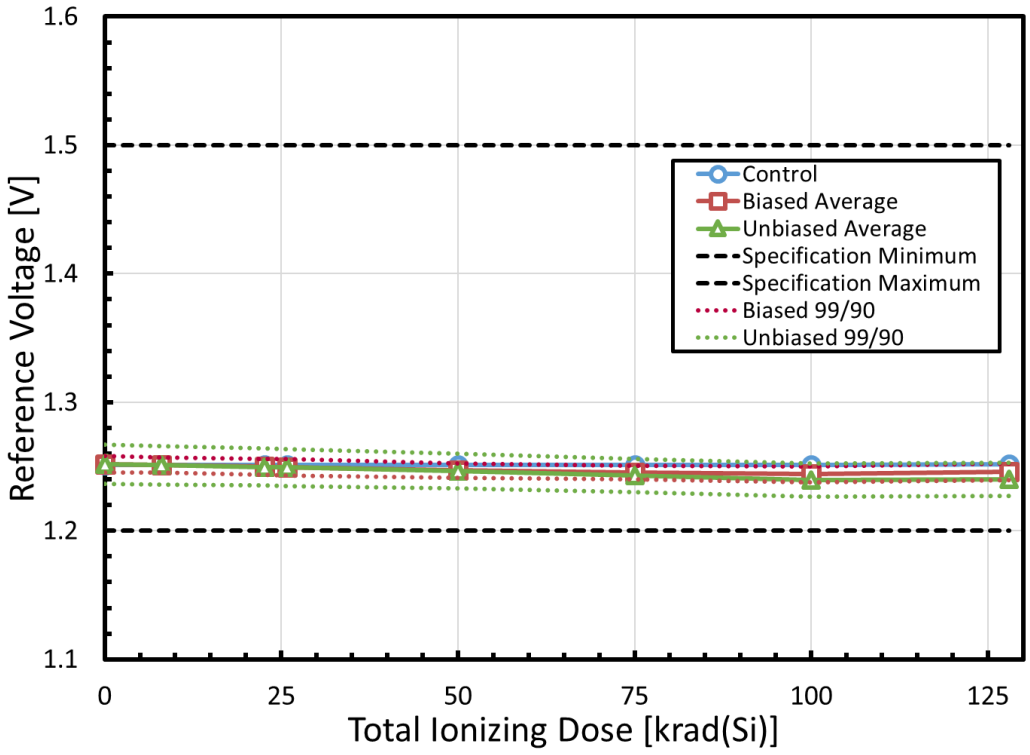

Fig. 5. Reference voltage over dose.

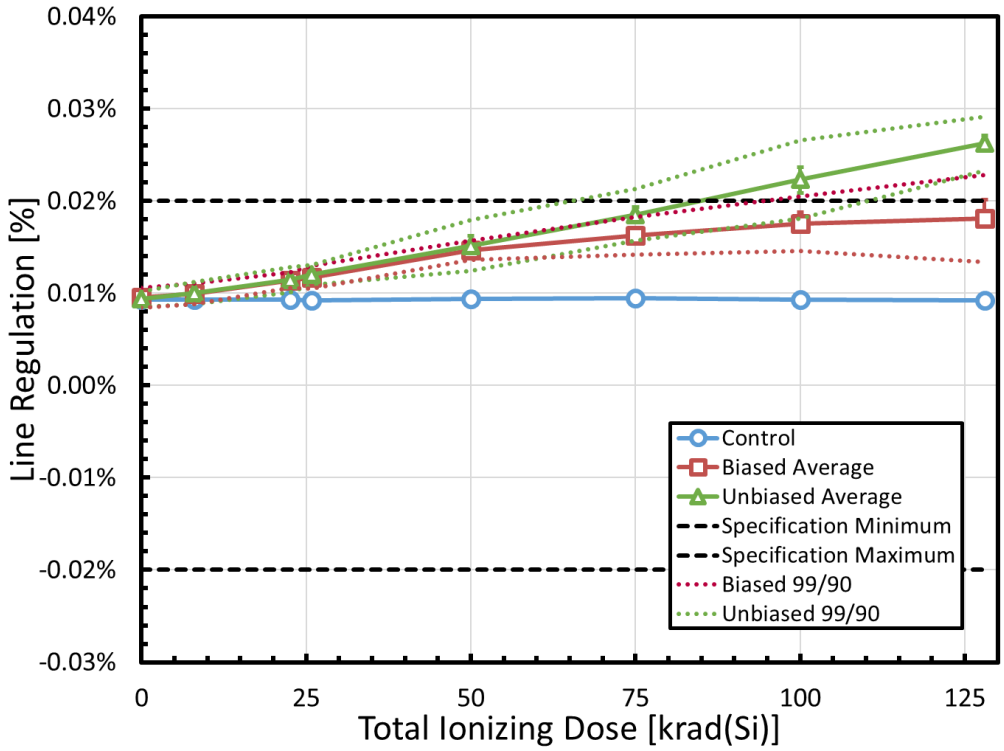

Fig. 6. Line regulation over dose.

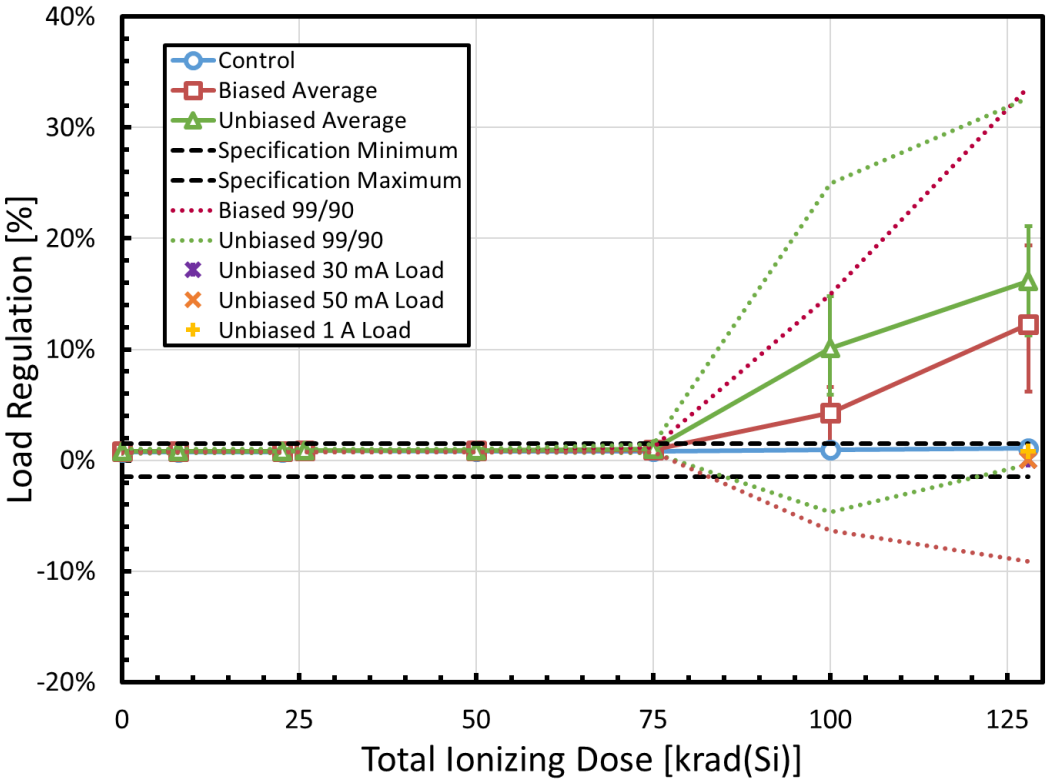

Fig. 7. Load Regulation over dose.

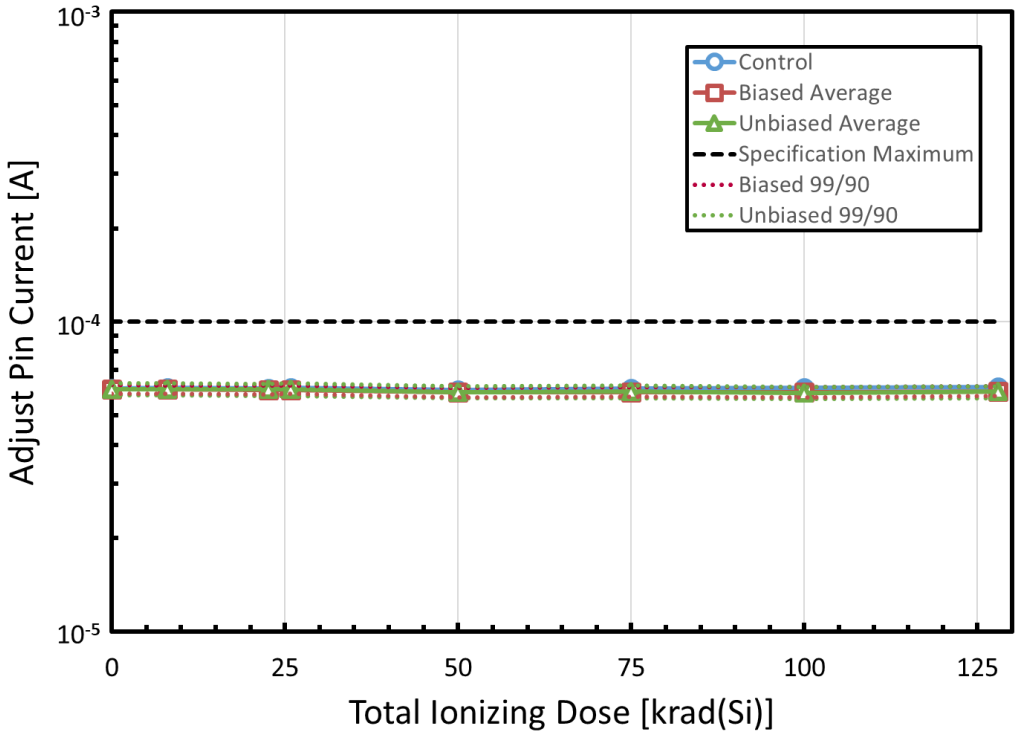

Fig. 8. Adjust Pin Current over dose.

Table 5. Raw data

Reference Voltage	Total Ionizing Dose							
	Pre-Rad	8 krad(Si)	22.6 krad(Si)	25.8 krad(Si)	50 krad(Si)	75 krad(Si)	100 krad	128 krad
Control (DUT11)	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
DUT1	1.25	1.25	1.25	1.25	1.25	1.24	1.24	1.24
DUT2	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
DUT3	1.25	1.25	1.25	1.25	1.25	1.25	1.24	1.25
DUT4	1.25	1.25	1.25	1.25	1.25	1.24	1.24	1.25
DUT5	1.25	1.25	1.25	1.25	1.25	1.24	1.24	1.25
DUT6	1.25	1.25	1.25	1.25	1.24	1.24	1.24	1.24
DUT7	1.25	1.25	1.25	1.25	1.24	1.24	1.24	1.24
DUT8	1.25	1.25	1.25	1.25	1.25	1.24	1.24	1.24
DUT9	1.26	1.26	1.26	1.26	1.25	1.25	1.24	1.25
DUT10	1.25	1.25	1.25	1.25	1.25	1.24	1.24	1.24
Specification Minimum	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Specification Maximum	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Biased Avg	1.25	1.25	1.25	1.25	1.25	1.25	1.24	1.25
Biased Std Dev	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biased +99/90	1.26	1.26	1.26	1.26	1.25	1.25	1.25	1.25
Biased -99/90	1.25	1.25	1.24	1.24	1.24	1.24	1.24	1.24
+Biased Error Bar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-Biased Error Bar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unbiased Avg	1.25	1.25	1.25	1.25	1.25	1.24	1.24	1.24
Unbiased Std Dev	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unbiased +99/90	1.27	1.27	1.26	1.26	1.26	1.26	1.25	1.25
Unbiased -99/90	1.24	1.24	1.24	1.23	1.23	1.23	1.23	1.23
+Unbiased Error Bar	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
-Unbiased Error Bar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Line Regulation	Total Ionizing Dose							
	Pre-Rad	8 krad(Si)	22.6 krad(Si)	25.8 krad(Si)	50 krad(Si)	75 krad(Si)	100 krad	125 krad
Control (DUT11)	0.009%	0.009%	0.009%	0.009%	0.009%	0.009%	0.009%	0.009%
DUT1	0.010%	0.010%	0.012%	0.012%	0.015%	0.017%	0.019%	0.020%
DUT2	0.009%	0.010%	0.011%	0.011%	0.015%	0.016%	0.017%	0.018%
DUT3	0.009%	0.010%	0.011%	0.011%	0.014%	0.016%	0.017%	0.018%
DUT4	0.010%	0.010%	0.011%	0.012%	0.015%	0.016%	0.017%	0.018%
DUT5	0.010%	0.010%	0.012%	0.012%	0.015%	0.016%	0.017%	0.018%
DUT6	0.009%	0.010%	0.011%	0.012%	0.015%	0.018%	0.023%	0.026%
DUT7	0.009%	0.010%	0.011%	0.012%	0.015%	0.018%	0.021%	0.026%
DUT8	0.009%	0.010%	0.012%	0.012%	0.015%	0.019%	0.024%	0.027%
DUT9	0.010%	0.010%	0.012%	0.012%	0.016%	0.019%	0.022%	0.027%
DUT10	0.009%	0.010%	0.011%	0.012%	0.014%	0.018%	0.023%	0.026%
Specification Minimum	-0.020%	-0.020%	-0.020%	-0.020%	-0.020%	-0.020%	-0.020%	-0.020%
Specification Maximum	0.020%	0.020%	0.020%	0.020%	0.020%	0.020%	0.020%	0.020%
Biased Avg	0.010%	0.010%	0.011%	0.012%	0.015%	0.016%	0.018%	0.018%
Biased Std Dev	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%
Biased +99/90	0.011%	0.011%	0.012%	0.013%	0.016%	0.018%	0.021%	0.023%
Biased -99/90	0.008%	0.009%	0.011%	0.010%	0.014%	0.014%	0.015%	0.013%
+Biased Error Bar	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%	0.002%
-Biased Error Bar	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.001%
Unbiased Avg	0.009%	0.010%	0.011%	0.012%	0.015%	0.019%	0.022%	0.026%
Unbiased Std Dev	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%	0.001%	0.001%
Unbiased +99/90	0.010%	0.011%	0.013%	0.013%	0.018%	0.021%	0.027%	0.029%
Unbiased -99/90	0.009%	0.009%	0.010%	0.011%	0.012%	0.016%	0.018%	0.023%
+Unbiased Error Bar	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%	0.001%	0.001%
-Unbiased Error Bar	0.000%	0.000%	0.000%	0.000%	0.001%	0.001%	0.002%	0.001%

Load Regulation	Total Ionizing Dose								Post-128 krad		
	Pre-Rad	8 krad(Si)	22.6 krad(Si)	25.8 krad(Si)	50 krad(Si)	75 krad(Si)	100 krad	125 krad	1 A Load	50 mA Load	30 mA Load
Control (DUT11)	0.75%	0.77%	0.77%	0.86%	0.78%	0.81%	0.95%	1.08%	0.71%	0.04%	0.02%
DUT1	0.81%	0.83%	0.85%	0.89%	0.90%	1.05%	6.62%	19.35%	6.30%		0.03%
DUT2	0.80%	0.83%	0.84%	0.84%	0.87%	0.98%	6.62%	15.31%	0.77%	0.05%	0.03%
DUT3	0.83%	0.85%	0.86%	0.87%	0.88%	0.97%	2.26%	10.31%	0.78%	0.05%	0.03%
DUT4	0.79%	0.82%	0.82%	0.83%	0.85%	0.95%	5.01%	10.04%	0.76%	0.05%	0.03%
DUT5	0.76%	0.78%	0.79%	0.84%	0.84%	0.91%	1.06%	6.20%	0.74%	0.05%	0.03%
DUT6	0.80%	0.82%	0.83%	0.86%	0.85%	0.97%	5.92%	13.74%	0.82%	0.06%	0.04%
DUT7	0.89%	0.88%	0.87%	0.88%	0.91%	1.07%	8.44%	19.04%	0.87%	0.06%	0.04%
DUT8	0.84%	0.85%	0.85%	0.87%	0.88%	1.02%	12.62%	15.58%	0.83%	0.06%	0.04%
DUT9	0.74%	0.77%	0.77%	0.79%	0.81%	1.21%	14.81%	21.10%	0.79%	0.05%	0.03%
DUT10	0.82%	0.84%	0.87%	0.87%	0.87%	0.99%	8.88%	11.28%	0.82%	0.06%	0.04%
Specification Minimum	-1.50%	-1.50%	-1.50%	-1.50%	-1.50%	-1.50%	-1.50%	-1.50%	-1.50%	-1.50%	-1.50%
Specification Maximum	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%
Biased Avg	0.80%	0.82%	0.83%	0.85%	0.87%	0.97%	4.31%	12.24%	1.87%	0.05%	0.03%
Biased Std Dev	0.02%	0.02%	0.03%	0.02%	0.02%	0.05%	2.28%	4.58%	2.22%	0.00%	0.00%
Biased +99/90	0.91%	0.92%	0.95%	0.96%	0.98%	1.19%	14.94%	33.63%	12.22%	0.05%	0.03%
Biased -99/90	0.69%	0.72%	0.71%	0.75%	0.76%	0.75%	-6.32%	-9.14%	-8.48%	0.04%	0.03%
+Biased Error Bar	0.03%	0.03%	0.03%	0.03%	0.03%	0.08%	2.31%	7.11%	4.44%	0.00%	0.00%
-Biased Error Bar	0.04%	0.04%	0.04%	0.02%	0.03%	0.06%	3.26%	6.04%	1.13%	0.00%	0.00%
Unbiased Avg	0.82%	0.83%	0.84%	0.85%	0.86%	1.05%	10.14%	16.15%	0.83%	0.06%	0.04%
Unbiased Std Dev	0.05%	0.04%	0.04%	0.03%	0.03%	0.09%	3.17%	3.54%	0.03%	0.00%	0.00%
Unbiased +99/90	1.05%	1.00%	1.02%	1.00%	1.01%	1.46%	24.93%	32.66%	0.95%	0.07%	0.05%
Unbiased -99/90	0.59%	0.66%	0.66%	0.71%	0.71%	0.65%	-4.66%	-0.37%	0.70%	0.04%	0.03%
+Unbiased Error Bar	0.07%	0.05%	0.03%	0.03%	0.04%	0.16%	4.68%	4.95%	0.05%	0.01%	0.00%
-Unbiased Error Bar	0.08%	0.06%	0.07%	0.06%	0.05%	0.08%	4.21%	4.86%	0.04%	0.00%	0.00%

Adjust Pin Current	Total Ionizing Dose							
	Pre-Rad	8 krad(Si)	22.6 krad(Si)	25.8 krad(Si)	50 krad(Si)	75 krad(Si)	100 krad	125 krad
Control (DUT11)	6.09E-05	6.11E-05	6.10E-05	6.10E-05	6.02E-05	6.09E-05	6.10E-05	6.15E-05
DUT1	5.98E-05	5.98E-05	5.95E-05	5.96E-05	5.84E-05	5.86E-05	5.83E-05	5.89E-05
DUT2	6.08E-05	6.07E-05	6.05E-05	6.05E-05	5.96E-05	5.97E-05	5.95E-05	6.00E-05
DUT3	6.02E-05	6.01E-05	5.99E-05	6.00E-05	5.89E-05	5.90E-05	5.89E-05	5.93E-05
DUT4	6.09E-05	6.08E-05	6.05E-05	6.06E-05	5.96E-05	5.98E-05	5.96E-05	6.01E-05
DUT5	6.08E-05	6.07E-05	6.05E-05	6.06E-05	5.94E-05	5.97E-05	5.95E-05	6.00E-05
DUT6	6.03E-05	6.01E-05	6.00E-05	6.01E-05	5.89E-05	5.91E-05	5.87E-05	5.90E-05
DUT7	6.02E-05	6.01E-05	6.00E-05	6.00E-05	5.88E-05	5.89E-05	5.87E-05	5.90E-05
DUT8	6.13E-05	6.11E-05	6.11E-05	6.12E-05	6.01E-05	6.02E-05	5.97E-05	6.01E-05
DUT9	6.13E-05	6.12E-05	6.10E-05	6.11E-05	5.98E-05	6.00E-05	5.96E-05	6.00E-05
DUT10	5.99E-05	5.98E-05	5.97E-05	5.98E-05	5.87E-05	5.89E-05	5.84E-05	5.87E-05
Specification Maximum	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
Biased Avg	6.05E-05	6.04E-05	6.02E-05	6.03E-05	5.92E-05	5.93E-05	5.92E-05	5.97E-05
Biased Std Dev	4.15E-07	3.84E-07	4.18E-07	3.88E-07	4.50E-07	4.71E-07	4.79E-07	4.54E-07
Biased +99/90	6.24E-05	6.22E-05	6.21E-05	6.21E-05	6.13E-05	6.15E-05	6.14E-05	6.18E-05
Biased -99/90	5.86E-05	5.86E-05	5.82E-05	5.85E-05	5.71E-05	5.71E-05	5.69E-05	5.75E-05
+Biased Error Bar	3.73E-07	3.74E-07	3.59E-07	3.57E-07	4.03E-07	4.16E-07	4.00E-07	3.92E-07
-Biased Error Bar	6.59E-07	6.19E-07	6.79E-07	6.18E-07	7.61E-07	7.77E-07	8.24E-07	7.34E-07
Unbiased Avg	6.06E-05	6.05E-05	6.04E-05	6.04E-05	5.93E-05	5.94E-05	5.90E-05	5.94E-05
Unbiased Std Dev	5.95E-07	5.77E-07	5.80E-07	6.14E-07	5.70E-07	5.69E-07	5.50E-07	5.65E-07
Unbiased +99/90	6.34E-05	6.32E-05	6.31E-05	6.33E-05	6.19E-05	6.21E-05	6.16E-05	6.20E-05
Unbiased -99/90	5.78E-05	5.78E-05	5.77E-05	5.76E-05	5.66E-05	5.68E-05	5.65E-05	5.67E-05
+Unbiased Error Bar	7.23E-07	7.40E-07	7.57E-07	7.99E-07	8.20E-07	8.17E-07	7.24E-07	7.40E-07
-Unbiased Error Bar	6.77E-07	6.43E-07	6.32E-07	6.69E-07	5.55E-07	5.41E-07	6.52E-07	6.46E-07

8. SUMMARY

Reference voltage and adjustment pin current parameters did not go out of specification during the entire irradiation up to 128 krad(Si). Line and Load regulation parameters went above maximum specifications after 75 krad(Si).

9. REFERENCES

1) Department of Defense "Test Method Standard Microcircuits," MIL-STD-883 Test Method 1019.9 Ionizing radiation (total dose) test procedure, June 7, 2013, https://landandmaritimeapps.dla.mil/Downloads/MilSpec/Docs/MIL-STD-883/std883.pdf.
2) Intersil datasheet FN4560 Rev 10.00 March 25, 2014