



LDR Report
17-0312 11/13/19 R1.1

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***Low Dose Rate (LDR) Radiation Testing of the RH5596, 100MHz to 40GHz
Linear-in-dB RMS Power Detector with 35dB Dynamic Range for Linear
Technology***

Customer: Linear Technology, PO# X78204L

RAD Job Number: 17-0312

Part Type Tested: RH5596, 100MHz to 40GHz Linear-in-dB RMS Power Detector with 35dB Dynamic Range

Traceability Information: Manufacturer: Linear Technology. See photograph of unit under test in Appendix A.

Quantity of Units: 12 units received, 5 units for biased irradiation, 5 units for unbiased irradiation and 2 units for control. Serial numbers 13, 14, 15, 16 and 17 were biased during irradiation, serial numbers 18, 19, 20, 21 and 22 were unbiased during irradiation and serial numbers 23 and 24 were used as control. See Appendix B for the radiation bias schematic.

Radiation and Electrical Test Increments: 10mrad(Si)/s ionizing radiation to 50krad(Si) and 100krad(Si). All electrical tests were performed by Linear Technology.

Pre-Irradiation Burn-In: Burn-In performed by Linear Technology prior to receipt by RAD

Overtest and Post-Irradiation Anneal: None Specified.

Radiation Test Standard: MIL-STD-883 TM1019 Condition D

Test Hardware and Software: All electrical tests were performed by Linear Technology.

Facility and Radiation Source: Aeroflex RAD's Longmire Laboratories, Colorado Springs, CO. Gamma rays provided by JLSA GB150 Co60 source. Dosimetry performed by Air Ionization Chamber (AIC) traceable to NIST. Aeroflex RAD's dosimetry has been audited by DLA and Aeroflex RAD has been awarded Laboratory Suitability for MIL-STD-750 and MIL-STD-883 TM 1019.

Irradiation and Test Temperature: Room temperature controlled to 24°C±6°C per MIL-STD-883.

Low Dose Rate Test Result: PASSED the low dose rate test to the maximum tested dose level of 100krad(Si) with all parameters remaining within their datasheet specifications.



1.0. Overview and Background

It is well known that total dose ionizing radiation can cause parametric degradation and ultimately functional failure in electronic devices. The damage occurs via electron-hole pair production, transport and trapping in the dielectric regions. In advanced CMOS technology nodes (0.6 μ m and smaller) the bulk of the damage is manifested in the thicker isolation regions, such as shallow trench or local oxidation of silicon (LOCOS) oxides (also known as "birds-beak" oxides). However, many linear and mixed signal devices that utilize bipolar minority carrier elements exhibit an enhanced low dose rate sensitivity (ELDRS). At this time there is no known or accepted *a priori* method for predicting susceptibility to ELDRS or simulating the low dose rate sensitivity with a "conventional" room temperature 50-300rad(Si)/s irradiation (Condition A in MIL-STD-883 TM 1019). Over the past 10 years a number of accelerating techniques have been examined, including an elevated temperature anneal, such as that used for MOS devices (see ASTM-F-1892 for more technical details) and irradiating at various temperatures. However, none of these techniques have proven useful across the wide variety of linear and/or mixed signal devices used in spaceborne applications.

The latest requirement incorporated in MIL-STD-883 TM 1019 requires that devices that could potentially exhibit ELDRS "shall be tested either at the intended application dose rate, at a prescribed low dose rate to an overtest radiation level, or with an accelerated test such as an elevated temperature irradiation test that includes a parameter delta design margin". While the recently released MIL-STD-883H TM 1019 allows for accelerated testing, the requirements for this are to essentially perform a low dose rate ELDRS test to verify the suitability of the acceleration method on the component of interest before the acceleration technique can be instituted. Based on the limitations of accelerated testing and to meet the requirements of MIL-STD-883H TM1019 Condition D, we have performed a low dose rate test at 10mrad(Si)/s.

2.0. Radiation Test Apparatus

The low dose rate testing described in this final report was performed using the facilities at Aeroflex RAD's Longmire Laboratories in Colorado Springs, CO. The low dose rate source is a GB-150 irradiator modified to provide a panoramic exposure. The Co-60 rods are held in the base of the irradiator heavily shielded by lead. During the irradiation exposures the rod is raised by an electronic timer/controller and the exposure is performed in air. The dose rate for this irradiator in this configuration ranges from approximately 1mrad(Si)/s to a maximum of approximately 50rad(Si)/s, determined by the distance from the source. For low dose rate testing described in this report, the devices are placed approximately 2-meters from the Co-60 rods. The irradiator calibration is maintained by Aeroflex RAD's Longmire Laboratories using air ionization chamber (AIC) dosimetry traceable to the National Institute of Standards and Technology (NIST). Figure 2.1 shows a photograph of the GB-150 Co-60 irradiator at Aeroflex RAD's Longmire Laboratory facility.



Figure 2.1. Aeroflex RAD's Co-60 irradiator. The dose rate is obtained by positioning the device-under-test at a fixed distance from the gamma cell. The dose rate for this irradiator varies from approximately 50rad(Si)/s close to the rods down to <1mrad(Si)/s at a distance of approximately 4-meters.



3.0. Radiation Test Conditions

The RH5596 100MHz to 40GHz Linear-in-dB RMS Power Detector with 35dB Dynamic Range described in this final report were irradiated under 2 different conditions; biased using a single-sided supply potential of 3.3V, and unbiased with all pins tied to ground. See Appendix B for details on the biasing conditions during radiation exposure. In our opinion, this bias circuit satisfies the requirements of MIL-STD-883 TM1019 Section 3.9.3 Bias and Loading Conditions which states "The bias applied to the test devices shall be selected to produce the greatest radiation induced damage or the worst-case damage for the intended application, if known. While maximum voltage is often worst case some bipolar linear device parameters (e.g. input bias current or maximum output load current) exhibit more degradation with 0 V bias."

The devices were irradiated to a maximum total ionizing dose level of 100krad(Si) with incremental reading at 50krad(Si). Electrical testing occurred within one hour following the end of each irradiation segment. For intermediate irradiations, the units were tested and returned to total dose exposure within two hours from the end of the previous radiation increment. The radiation exposure bias board was positioned in the Co-60 cell to provide the targeted dose rate of 10mrad(Si)/s and was located inside a lead-aluminum enclosure. The lead-aluminum enclosure is required under MIL-STD-883 TM1019 Section 3.4 that reads as follows: "Lead/Aluminum (Pb/Al) container. Test specimens shall be enclosed in a Pb/Al container to minimize dose enhancement effects caused by low-energy, scattered radiation. A minimum of 1.5 mm Pb, surrounding an inner shield of at least 0.7 mm Al, is required. This Pb/Al container produces an approximate charged particle equilibrium for Si and for TLDs such as CaF₂. The radiation field intensity shall be measured inside the Pb/Al container (1) initially, (2) when the source is changed, or (3) when the orientation or configuration of the source, container, or test-fixture is changed. This measurement shall be performed by placing a dosimeter (e.g., a TLD) in the device-irradiation container at the approximate test-device position. If it can be demonstrated that low energy scattered radiation is small enough that it will not cause dosimetry errors due to dose enhancement, the Pb/Al container may be omitted".

The final dose rate within the lead-aluminum box was determined based on air ionization chamber (AIC) dosimetry measurements just prior to the beginning of the total dose irradiations. The final dose rate for this work was 10mrad(Si)/s with a precision of $\pm 5\%$.



4.0. Tested Parameters

During the enhanced low dose rate sensitivity testing the following electrical parameters were measured pre- and post-irradiation:

1. Shutdown Current1 (A) @ EN=0.6V, VCC=3.6V
2. Active Supply Current1 (A) @ EN=1.1V, VCC=3.6V
3. Shutdown Supply Current (A) @ EN=0.0V, VCC=3.3V
4. Active Supply Current (A) @ EN=3.3V, VCC=3.3V
5. EN Pin Input Current (A) @ EN=3.6V, VCC=3.6V
6. Output DC Voltage1 (V) @ EN=1.1V, VCC=3.3V,RFIN=GND
7. Output DC Voltage2 (V) @ PIN=10dB, EN=1.1V, VCC=3.3V, RFIN=2.14GHz
8. Output Voltage Droop (V) @ ISINK=25mA
9. Logarithmic Slope (V/dB) @ RFIN=2.14GHz
10. Logarithmic Intercept (dB) @ RFIN=2.14GHz

Appendix C details the measured parameters, test conditions, pre-irradiation specification and measurement resolution for each of the measurements.

The parametric data was obtained as "read and record" and all the raw data plus an attributes summary are contained in this report as well as in a separate Excel file. The attributes data contains the average, standard deviation and the average with the KTL values applied. The KTL value used in this work is 2.742 per MIL-HDBK-814 using one sided tolerance limits of 90/90 and a 5-piece sample size. The 90/90 KTL values were selected to match the statistical levels specified in the MIL-PRF-38535 sampling plan for the qualification of a radiation hardness assured (RHA) component. Note that the following criteria must be met for a device to pass the low dose rate test: following the radiation exposure each of the 5 pieces irradiated under electrical bias shall pass the specification value. The units irradiated without electrical bias and the KTL statistics are included in this report for reference only. If any of the 5 pieces irradiated under electrical bias exceed the device post radiation data sheet specification limits, then the lot could be logged as a failure.



5.0. LDR Test Results

Based on this criterion the RH5596 100MHz to 40GHz Linear-in-dB RMS Power Detector with 35dB Dynamic Range (from the lot traceability information provided on the first page of this test report) PASSED the low dose rate test to the maximum tested dose level of 100krad(Si) with all parameters remaining within their datasheet specifications.

Figures 5.1 through 5.10 show plots of all the measured parameters versus total ionizing dose while Tables 5.1 - 5.10 show the corresponding raw data for each of these parameters. In the data plots the solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the units irradiated with all pins tied to ground. The black lines (solid or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the sample irradiated in the biased condition while the shaded lines (solid or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the sample irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan. Appendix D lists the figures used in this section to facilitate the location of a particular parameter.

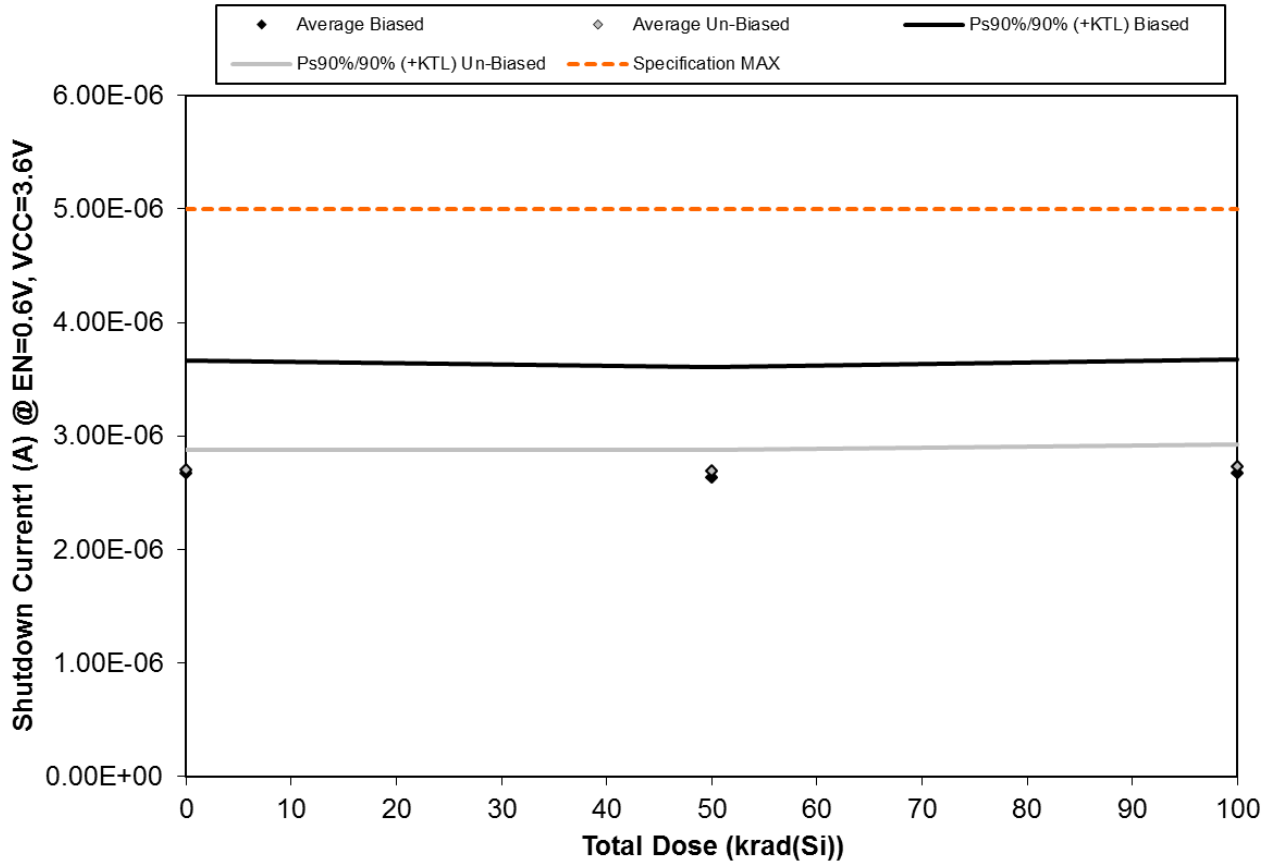


Figure 5.1. Plot of Shutdown Current1 (A) @ EN=0.6V, VCC=3.6V versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



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Table 5.1. Raw data for Shutdown Current1 (A) @ EN=0.6V, VCC=3.6V versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Shutdown Current1 (A) @ EN=0.6V, VCC=3.6V	Total Dose (krad(Si))		
	0	50	100
Device			
13	3.11E-06	3.08E-06	3.12E-06
14	2.83E-06	2.78E-06	2.79E-06
15	2.19E-06	2.17E-06	2.17E-06
16	2.43E-06	2.40E-06	2.44E-06
17	2.79E-06	2.74E-06	2.82E-06
18	2.67E-06	2.67E-06	2.68E-06
19	2.76E-06	2.75E-06	2.80E-06
20	2.63E-06	2.62E-06	2.66E-06
21	2.78E-06	2.77E-06	2.81E-06
22	2.68E-06	2.65E-06	2.69E-06
23	2.68E-06	2.65E-06	
24	2.53E-06	2.50E-06	
Biased Statistics			
Average Biased	2.67E-06	2.63E-06	2.67E-06
Std Dev Biased	3.63E-07	3.56E-07	3.68E-07
Ps90%/90% (+KTL) Biased	3.67E-06	3.61E-06	3.68E-06
Ps90%/90% (-KTL) Biased	1.68E-06	1.66E-06	1.66E-06
Un-Biased Statistics			
Average Un-Biased	2.70E-06	2.69E-06	2.73E-06
Std Dev Un-Biased	6.37E-08	6.59E-08	7.13E-08
Ps90%/90% (+KTL) Un-Biased	2.88E-06	2.87E-06	2.92E-06
Ps90%/90% (-KTL) Un-Biased	2.53E-06	2.51E-06	2.53E-06
Specification MAX	5.00E-06	5.00E-06	5.00E-06
Status	PASS	PASS	PASS

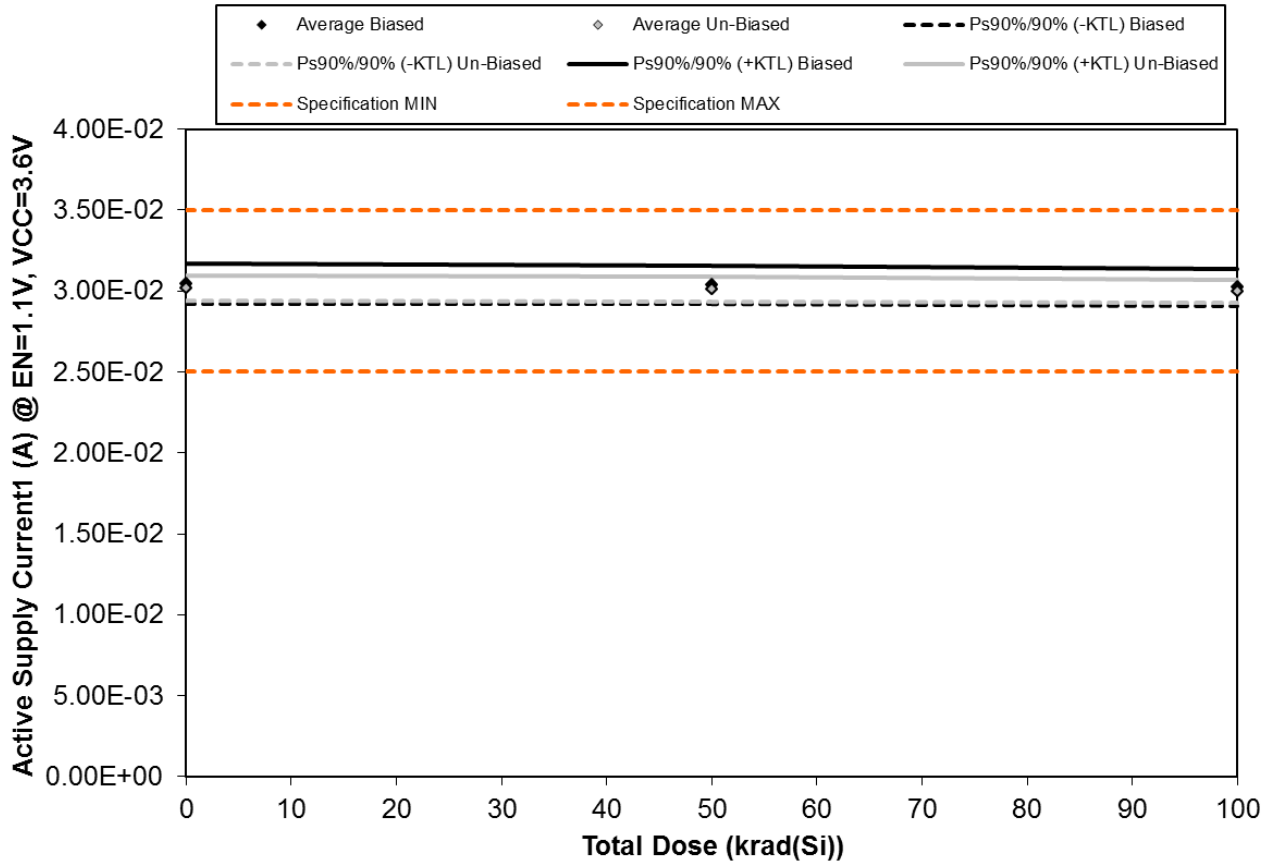


Figure 5.2. Plot of Active Supply Current1 (A) @ EN=1.1V, VCC=3.6V versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



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Table 5.2. Raw data for Active Supply Current1 (A) @ EN=1.1V, VCC=3.6V versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Active Supply Current1 (A) @ EN=1.1V, VCC=3.6V	Total Dose (krad(Si))		
	0	50	100
Device			
13	3.10E-02	3.09E-02	3.08E-02
14	3.07E-02	3.06E-02	3.04E-02
15	3.02E-02	3.01E-02	3.00E-02
16	2.98E-02	2.98E-02	2.97E-02
17	3.05E-02	3.04E-02	3.03E-02
18	3.00E-02	2.99E-02	2.98E-02
19	3.07E-02	3.06E-02	3.04E-02
20	3.03E-02	3.02E-02	3.01E-02
21	3.01E-02	3.00E-02	2.99E-02
22	3.00E-02	2.99E-02	2.97E-02
23	2.97E-02	2.96E-02	
24	3.07E-02	3.07E-02	
Biased Statistics			
Average Biased	3.04E-02	3.04E-02	3.02E-02
Std Dev Biased	4.48E-04	4.30E-04	4.18E-04
Ps90%/90% (+KTL) Biased	3.17E-02	3.15E-02	3.14E-02
Ps90%/90% (-KTL) Biased	2.92E-02	2.92E-02	2.91E-02
Un-Biased Statistics			
Average Un-Biased	3.02E-02	3.01E-02	3.00E-02
Std Dev Un-Biased	2.83E-04	2.78E-04	2.66E-04
Ps90%/90% (+KTL) Un-Biased	3.10E-02	3.09E-02	3.07E-02
Ps90%/90% (-KTL) Un-Biased	2.94E-02	2.93E-02	2.93E-02
Specification MIN	2.50E-02	2.50E-02	2.50E-02
Status	PASS	PASS	PASS
Specification MAX	3.50E-02	3.50E-02	3.50E-02
Status	PASS	PASS	PASS

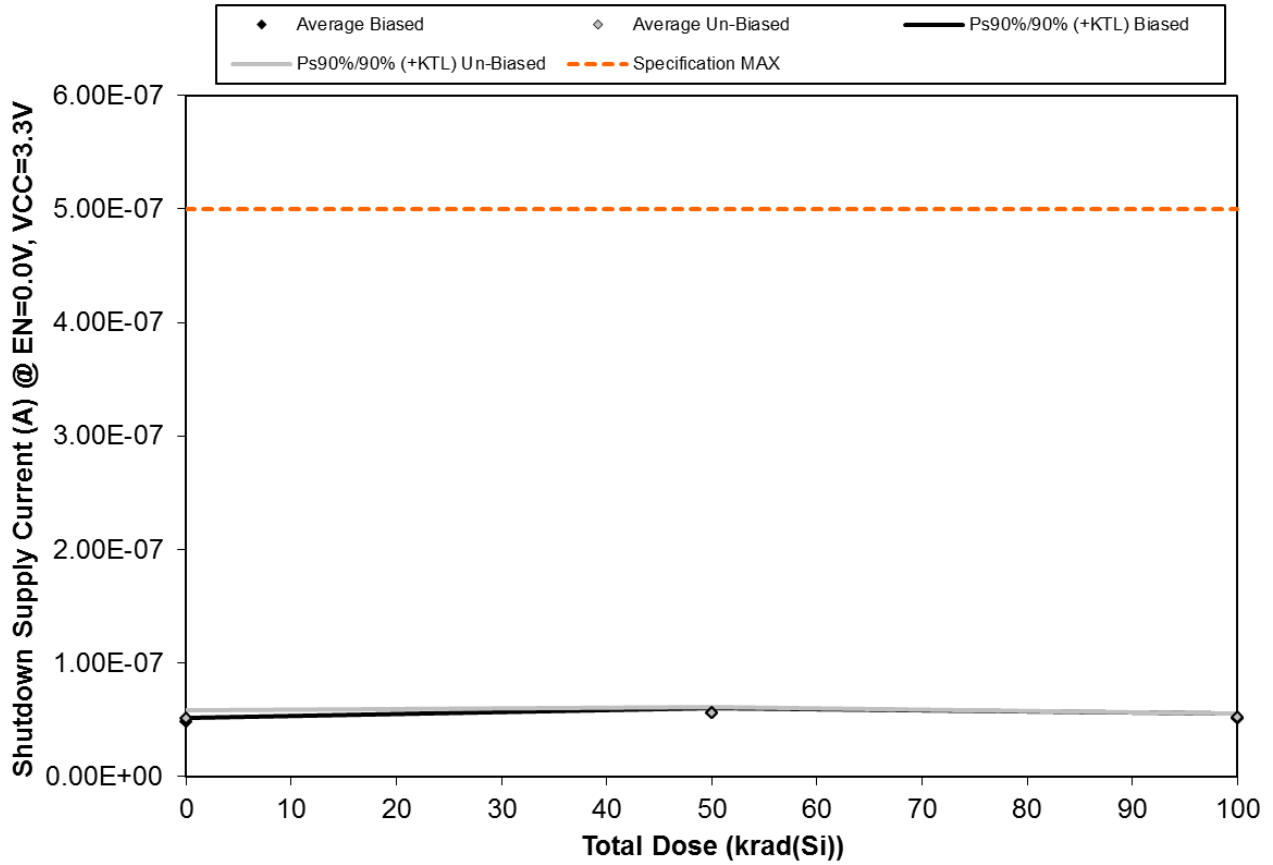


Figure 5.3. Plot of Shutdown Supply Current (A) @ EN=0.0V, VCC=3.3V versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



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Table 5.3. Raw data for Shutdown Supply Current (A) @ EN=0.0V, VCC=3.3V versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Shutdown Supply Current (A) @ EN=0.0V, VCC=3.	Total Dose (krad(Si))		
	0	50	100
Device			
13	4.80E-08	5.62E-08	5.32E-08
14	4.89E-08	5.58E-08	5.12E-08
15	4.72E-08	5.24E-08	4.97E-08
16	4.80E-08	5.72E-08	5.20E-08
17	5.05E-08	5.64E-08	5.21E-08
18	5.28E-08	5.83E-08	5.11E-08
19	5.27E-08	5.78E-08	5.29E-08
20	5.07E-08	5.70E-08	5.22E-08
21	5.43E-08	5.43E-08	5.08E-08
22	4.81E-08	5.45E-08	5.34E-08
23	5.08E-08	5.83E-08	
24	4.93E-08	5.37E-08	
Biased Statistics			
Average Biased	4.85E-08	5.56E-08	5.16E-08
Std Dev Biased	1.26E-09	1.87E-09	1.29E-09
Ps90%/90% (+KTL) Biased	5.20E-08	6.07E-08	5.52E-08
Ps90%/90% (-KTL) Biased	4.51E-08	5.05E-08	4.81E-08
Un-Biased Statistics			
Average Un-Biased	5.17E-08	5.64E-08	5.21E-08
Std Dev Un-Biased	2.39E-09	1.88E-09	1.12E-09
Ps90%/90% (+KTL) Un-Biased	5.83E-08	6.15E-08	5.51E-08
Ps90%/90% (-KTL) Un-Biased	4.52E-08	5.12E-08	4.90E-08
Specification MAX	5.00E-07	5.00E-07	5.00E-07
Status	PASS	PASS	PASS

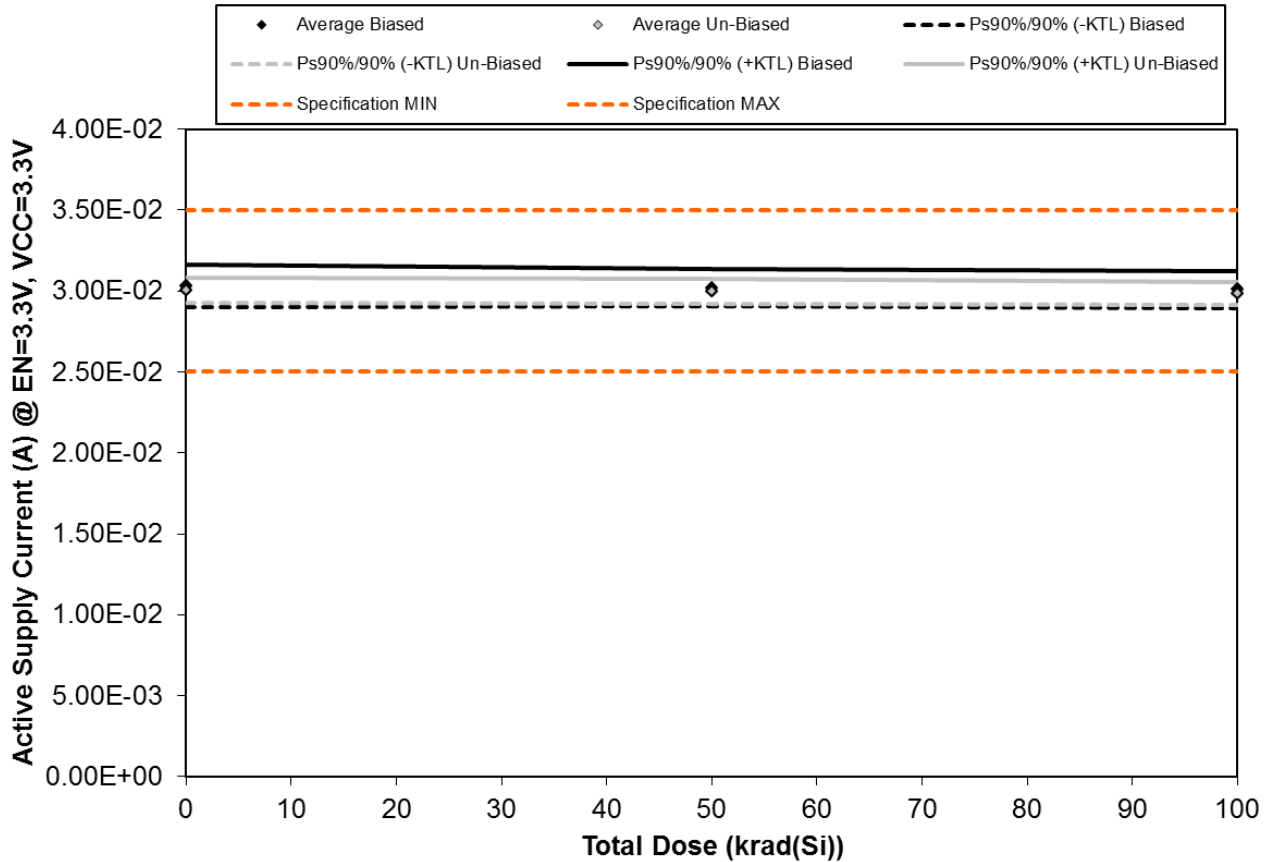


Figure 5.4. Plot of Active Supply Current (A) @ EN=3.3V, VCC=3.3V versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



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Table 5.4. Raw data for Active Supply Current (A) @ EN=3.3V, VCC=3.3V versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Active Supply Current (A) @ EN=3.3V, VCC=3.3V	Total Dose (krad(Si))		
	0	50	100
Device			
13	3.09E-02	3.07E-02	3.06E-02
14	3.05E-02	3.05E-02	3.03E-02
15	3.01E-02	2.99E-02	2.98E-02
16	2.96E-02	2.96E-02	2.96E-02
17	3.04E-02	3.03E-02	3.01E-02
18	2.99E-02	2.98E-02	2.97E-02
19	3.05E-02	3.04E-02	3.03E-02
20	3.01E-02	3.00E-02	2.99E-02
21	2.99E-02	2.98E-02	2.97E-02
22	2.98E-02	2.97E-02	2.96E-02
23	2.96E-02	2.95E-02	
24	3.06E-02	3.06E-02	
Biased Statistics			
Average Biased	3.03E-02	3.02E-02	3.01E-02
Std Dev Biased	4.85E-04	4.24E-04	4.14E-04
Ps90%/90% (+KTL) Biased	3.16E-02	3.14E-02	3.12E-02
Ps90%/90% (-KTL) Biased	2.90E-02	2.90E-02	2.90E-02
Un-Biased Statistics			
Average Un-Biased	3.00E-02	3.00E-02	2.98E-02
Std Dev Un-Biased	2.79E-04	2.80E-04	2.60E-04
Ps90%/90% (+KTL) Un-Biased	3.08E-02	3.07E-02	3.06E-02
Ps90%/90% (-KTL) Un-Biased	2.93E-02	2.92E-02	2.91E-02
Specification MIN	2.50E-02	2.50E-02	2.50E-02
Status	PASS	PASS	PASS
Specification MAX	3.50E-02	3.50E-02	3.50E-02
Status	PASS	PASS	PASS

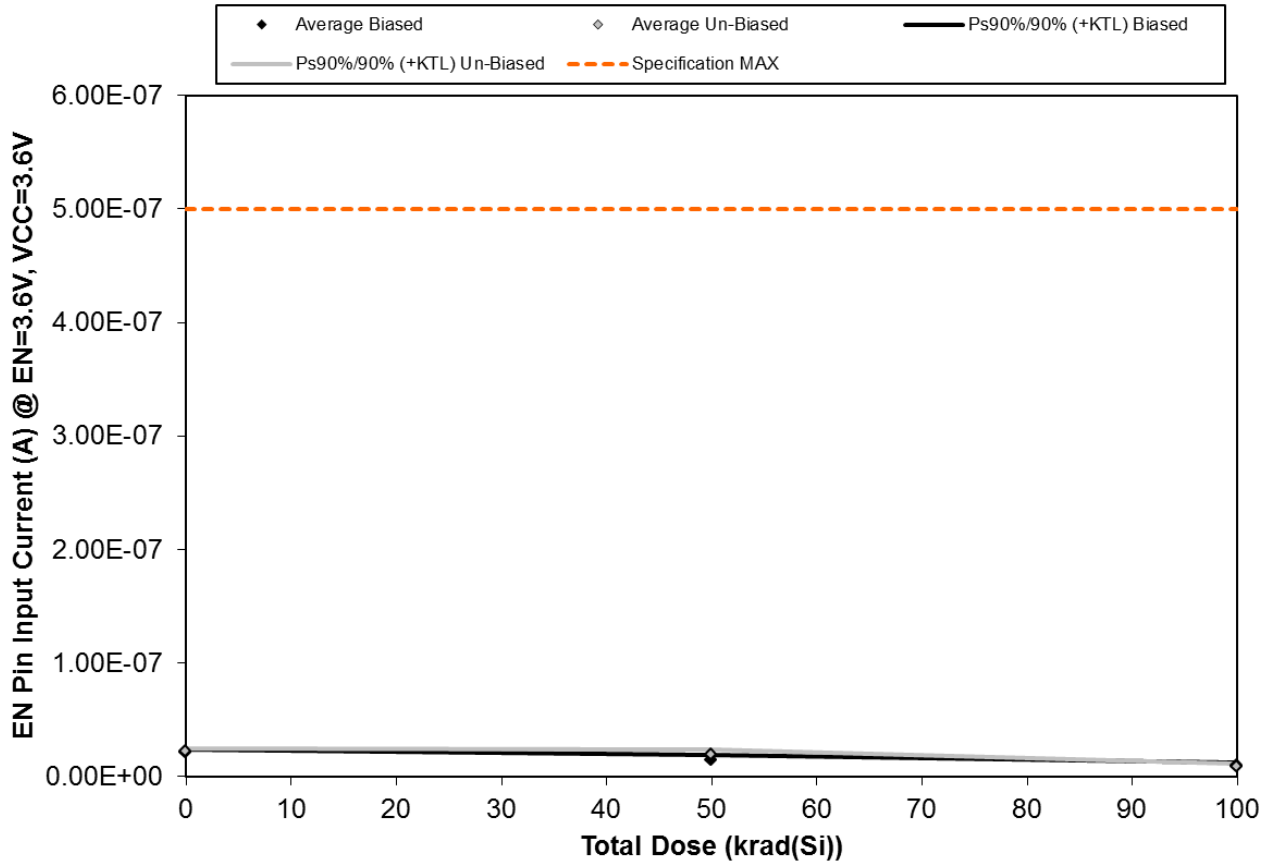


Figure 5.5. Plot of EN Pin Input Current (A) @ EN=3.6V, VCC=3.6V versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



Table 5.5. Raw data for EN Pin Input Current (A) @ EN=3.6V, VCC=3.6V versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

EN Pin Input Current (A) @ EN=3.6V, VCC=3.6V	Total Dose (krad(Si))		
	0	50	100
Device			
13	2.20E-08	1.30E-08	9.70E-09
14	2.05E-08	1.40E-08	8.39E-09
15	2.14E-08	1.50E-08	1.05E-08
16	2.12E-08	1.60E-08	1.05E-08
17	2.31E-08	1.70E-08	8.55E-09
18	2.35E-08	1.80E-08	1.02E-08
19	2.30E-08	1.90E-08	9.21E-09
20	2.28E-08	2.00E-08	8.03E-09
21	2.27E-08	2.10E-08	9.94E-09
22	2.10E-08	2.20E-08	8.03E-09
23	2.25E-08	2.30E-08	
24	2.04E-08	2.40E-08	
Biased Statistics			
Average Biased	2.16E-08	1.50E-08	9.52E-09
Std Dev Biased	9.76E-10	1.58E-09	1.01E-09
Ps90%/90% (+KTL) Biased	2.43E-08	1.93E-08	1.23E-08
Ps90%/90% (-KTL) Biased	1.90E-08	1.07E-08	6.74E-09
Un-Biased Statistics			
Average Un-Biased	2.26E-08	2.00E-08	9.08E-09
Std Dev Un-Biased	9.46E-10	1.58E-09	1.02E-09
Ps90%/90% (+KTL) Un-Biased	2.52E-08	2.43E-08	1.19E-08
Ps90%/90% (-KTL) Un-Biased	2.00E-08	1.57E-08	6.29E-09
Specification MAX	5.00E-07	5.00E-07	5.00E-07
Status	PASS	PASS	PASS

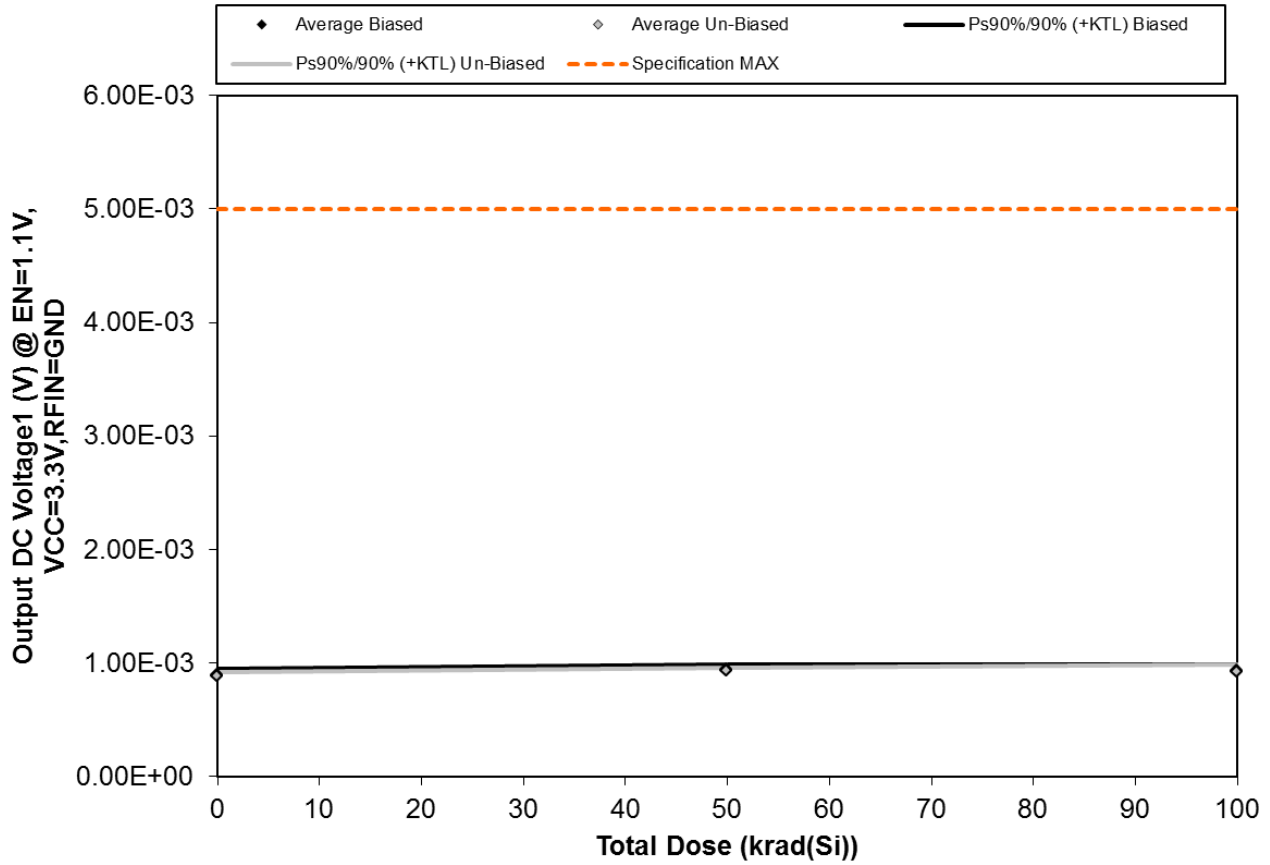


Figure 5.6. Plot of Output DC Voltage1 (V) @ EN=1.1V, VCC=3.3V, RFIN=GND versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



Table 5.6. Raw data for Output DC Voltage1 (V) @ EN=1.1V, VCC=3.3V,RFIN=GND versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Output DC Voltage1 (V) @ EN=1.1V, VCC=3.3V,RFIN=GND		Total Dose (krad(Si))		
Device		0	50	100
13	9.06E-04	9.30E-04	9.19E-04	
14	8.99E-04	9.61E-04	9.47E-04	
15	8.95E-04	9.44E-04	9.30E-04	
16	8.61E-04	9.21E-04	9.15E-04	
17	9.14E-04	9.52E-04	9.61E-04	
18	8.86E-04	9.41E-04	9.28E-04	
19	9.04E-04	9.33E-04	9.44E-04	
20	8.96E-04	9.33E-04	9.35E-04	
21	8.96E-04	9.40E-04	9.43E-04	
22	8.76E-04	9.19E-04	8.90E-04	
23	8.70E-04	9.09E-04		
24	9.06E-04	9.55E-04		
Biased Statistics				
Average Biased	8.95E-04	9.41E-04	9.34E-04	
Std Dev Biased	2.03E-05	1.62E-05	1.96E-05	
Ps90%/90% (+KTL) Biased	9.51E-04	9.86E-04	9.88E-04	
Ps90%/90% (-KTL) Biased	8.39E-04	8.97E-04	8.80E-04	
Un-Biased Statistics				
Average Un-Biased	8.92E-04	9.33E-04	9.28E-04	
Std Dev Un-Biased	1.08E-05	8.68E-06	2.21E-05	
Ps90%/90% (+KTL) Un-Biased	9.21E-04	9.57E-04	9.89E-04	
Ps90%/90% (-KTL) Un-Biased	8.62E-04	9.09E-04	8.67E-04	
Specification MAX	5.00E-03	5.00E-03	5.00E-03	
Status	PASS	PASS	PASS	

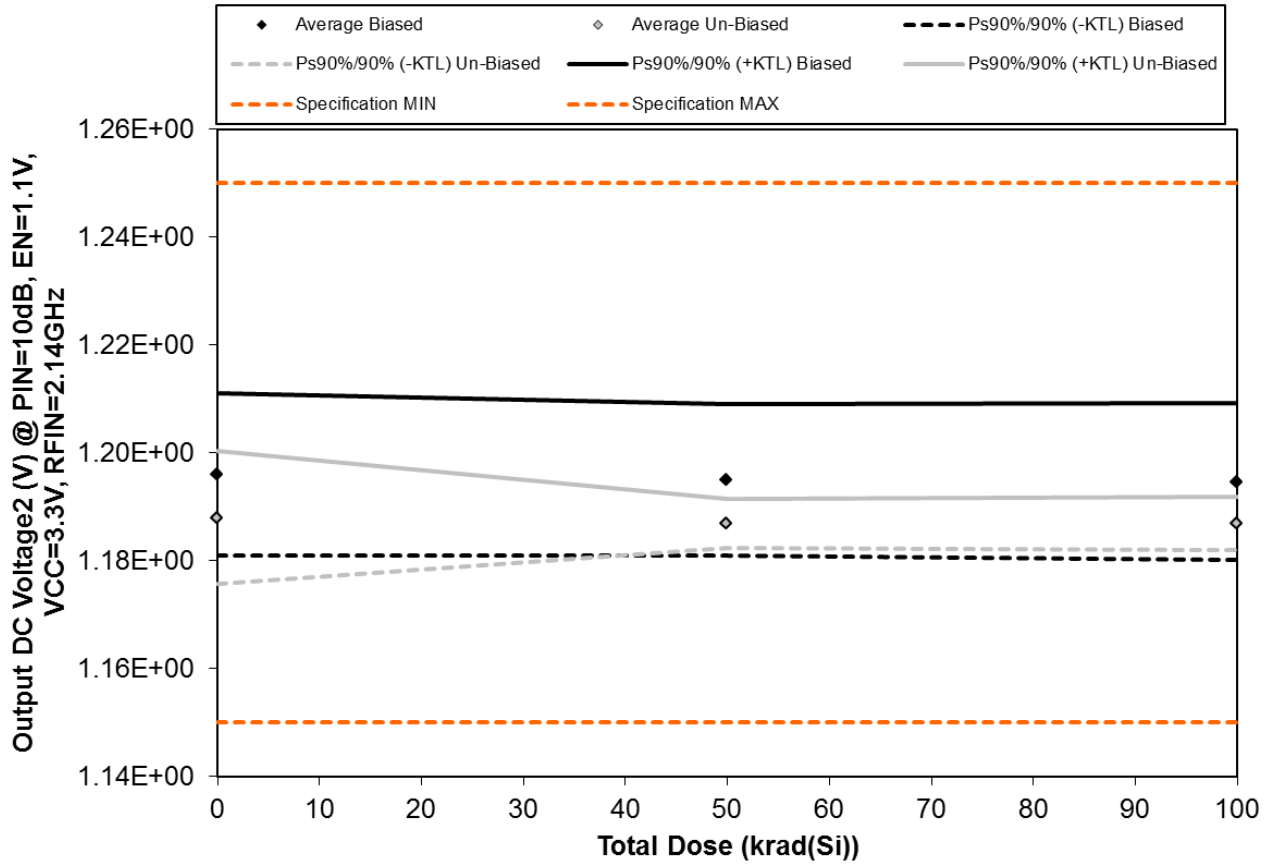


Figure 5.7. Plot of Output DC Voltage2 (V) @ PIN=10dB, EN=1.1V, VCC=3.3V, RFIN=2.14GHz versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



Table 5.7. Raw data for Output DC Voltage2 (V) @ PIN=10dB, EN=1.1V, VCC=3.3V, RFIN=2.14GHz versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Output DC Voltage2 (V) @ PIN=10dB, EN=1.1V, VCC=3.3V, RFIN=2.14GHz	Total Dose (krad(Si))		
	0	50	100
Device	0	50	100
13	1.20E+00	1.20E+00	1.20E+00
14	1.20E+00	1.20E+00	1.20E+00
15	1.19E+00	1.19E+00	1.19E+00
16	1.20E+00	1.19E+00	1.19E+00
17	1.19E+00	1.19E+00	1.19E+00
18	1.18E+00	1.19E+00	1.18E+00
19	1.19E+00	1.19E+00	1.19E+00
20	1.19E+00	1.19E+00	1.19E+00
21	1.19E+00	1.19E+00	1.19E+00
22	1.19E+00	1.19E+00	1.19E+00
23	1.19E+00	1.19E+00	
24	1.20E+00	1.20E+00	
Biased Statistics			
Average Biased	1.20E+00	1.20E+00	1.19E+00
Std Dev Biased	5.48E-03	5.11E-03	5.31E-03
Ps90%/90% (+KTL) Biased	1.21E+00	1.21E+00	1.21E+00
Ps90%/90% (-KTL) Biased	1.18E+00	1.18E+00	1.18E+00
Un-Biased Statistics			
Average Un-Biased	1.19E+00	1.19E+00	1.19E+00
Std Dev Un-Biased	4.47E-03	1.63E-03	1.82E-03
Ps90%/90% (+KTL) Un-Biased	1.20E+00	1.19E+00	1.19E+00
Ps90%/90% (-KTL) Un-Biased	1.18E+00	1.18E+00	1.18E+00
Specification MIN	1.15E+00	1.15E+00	1.15E+00
Status	PASS	PASS	PASS
Specification MAX	1.25E+00	1.25E+00	1.25E+00
Status	PASS	PASS	PASS

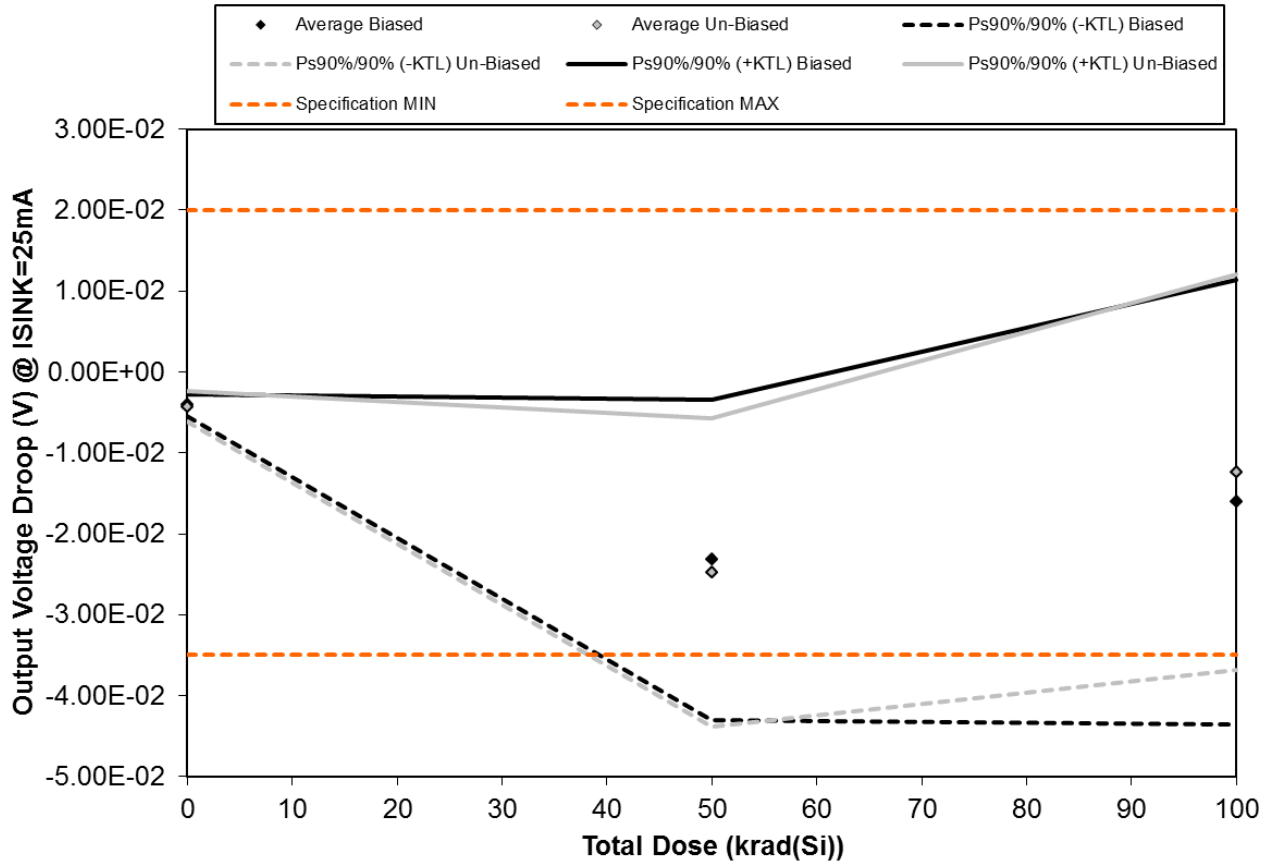


Figure 5.8. Plot of Output Voltage Droop (V) @ ISINK=25mA versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



Table 5.8. Raw data for Output Voltage Droop (V) @ ISINK=25mA versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Output Voltage Droop (V) @ ISINK=25mA	Total Dose (krad(Si))		
	0	50	100
Device			
13	-4.78E-03	-2.81E-02	-1.18E-02
14	-4.38E-03	-2.75E-02	-9.33E-03
15	-3.83E-03	-2.01E-02	-7.15E-03
16	-3.78E-03	-1.18E-02	-3.14E-02
17	-3.59E-03	-2.85E-02	-2.08E-02
18	-3.29E-03	-1.33E-02	-5.98E-03
19	-5.09E-03	-2.85E-02	-2.75E-02
20	-4.67E-03	-2.91E-02	-1.24E-02
21	-4.45E-03	-2.32E-02	-5.63E-03
22	-4.03E-03	-2.98E-02	-1.04E-02
23	-3.89E-03	-2.71E-02	
24	-3.64E-03	-6.32E-03	
Biased Statistics			
Average Biased	-4.07E-03	-2.32E-02	-1.61E-02
Std Dev Biased	4.93E-04	7.23E-03	1.00E-02
Ps90%/90% (+KTL) Biased	-2.72E-03	-3.39E-03	1.14E-02
Ps90%/90% (-KTL) Biased	-5.42E-03	-4.30E-02	-4.36E-02
Un-Biased Statistics			
Average Un-Biased	-4.31E-03	-2.48E-02	-1.24E-02
Std Dev Un-Biased	6.85E-04	6.95E-03	8.92E-03
Ps90%/90% (+KTL) Un-Biased	-2.43E-03	-5.72E-03	1.21E-02
Ps90%/90% (-KTL) Un-Biased	-6.18E-03	-4.38E-02	-3.69E-02
Specification MIN	-3.50E-02	-3.50E-02	-3.50E-02
Status	PASS	PASS	PASS
Specification MAX	2.00E-02	2.00E-02	2.00E-02
Status	PASS	PASS	PASS

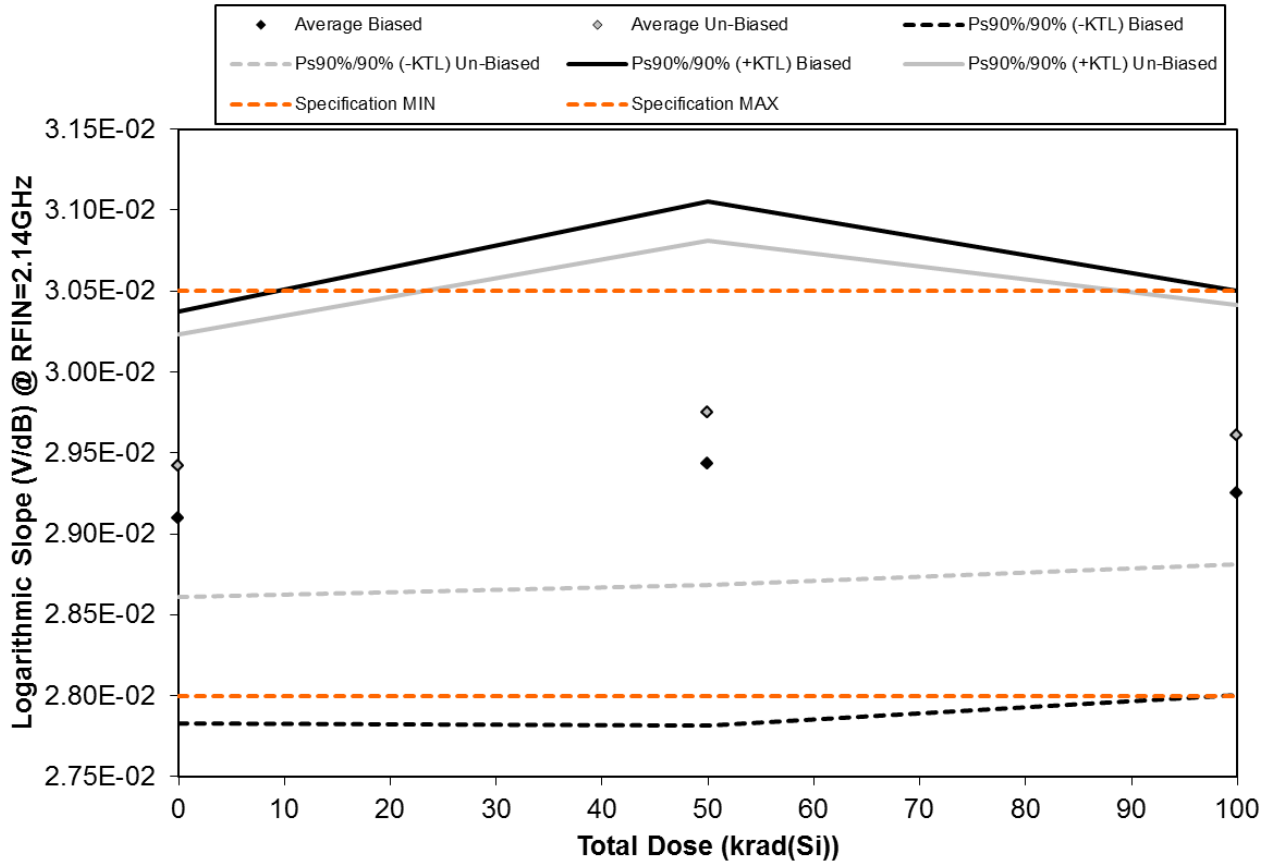


Figure 5.9. Plot of Logarithmic Slope (V/dB) @ RFIN=2.14GHz versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



Table 5.9. Raw data for Logarithmic Slope (V/dB) @ RFIN=2.14GHz versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Logarithmic Slope (V/dB) @ RFIN=2.14GHz	Total Dose (krad(Si))		
	0	50	100
Device			
13	2.97E-02	3.01E-02	2.97E-02
14	2.95E-02	3.00E-02	2.97E-02
15	2.88E-02	2.90E-02	2.86E-02
16	2.87E-02	2.88E-02	2.92E-02
17	2.88E-02	2.92E-02	2.90E-02
18	2.93E-02	2.94E-02	2.94E-02
19	2.94E-02	2.98E-02	2.95E-02
20	2.97E-02	3.01E-02	3.01E-02
21	2.90E-02	2.93E-02	2.94E-02
22	2.97E-02	3.02E-02	2.96E-02
23	2.91E-02	2.94E-02	
24	2.91E-02	2.92E-02	
Biased Statistics			
Average Biased	2.91E-02	2.94E-02	2.93E-02
Std Dev Biased	4.64E-04	5.90E-04	4.56E-04
Ps90%/90% (+KTL) Biased	3.04E-02	3.11E-02	3.05E-02
Ps90%/90% (-KTL) Biased	2.78E-02	2.78E-02	2.80E-02
Un-Biased Statistics			
Average Un-Biased	2.94E-02	2.97E-02	2.96E-02
Std Dev Un-Biased	2.95E-04	3.88E-04	2.92E-04
Ps90%/90% (+KTL) Un-Biased	3.02E-02	3.08E-02	3.04E-02
Ps90%/90% (-KTL) Un-Biased	2.86E-02	2.87E-02	2.88E-02
Specification MIN	2.80E-02	2.80E-02	2.80E-02
Status	PASS	PASS	PASS
Specification MAX	3.05E-02	3.05E-02	3.05E-02
Status	PASS	PASS	PASS

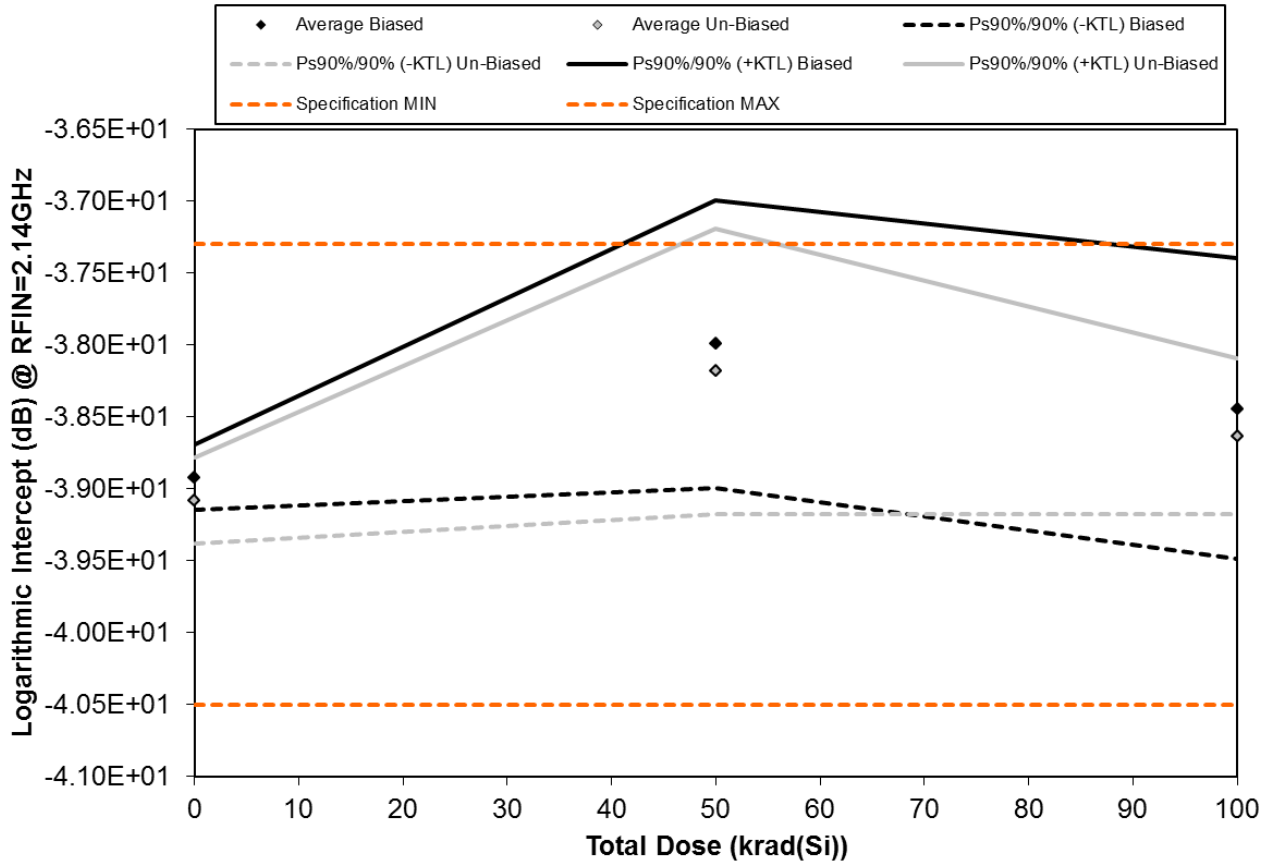


Figure 5.10. Plot of Logarithmic Intercept (dB) @ RFIN=2.14GHz versus total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the upper and/or lower confidence limits, as determined by KTL statistics, on the samples irradiated in the unbiased condition. The red dotted line(s) are the pre- and/or post-irradiation minimum and/or maximum specification value as defined in the datasheet and/or test plan.



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Table 5.10. Raw data for Logarithmic Intercept (dB) @ RFIN=2.14GHz versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Logarithmic Intercept (dB) @ RFIN=2.14GHz	Total Dose (krad(Si))		
	0	50	100
Device			
13	-3.89E+01	-3.78E+01	-3.88E+01
14	-3.90E+01	-3.79E+01	-3.87E+01
15	-3.88E+01	-3.79E+01	-3.86E+01
16	-3.90E+01	-3.86E+01	-3.79E+01
17	-3.89E+01	-3.78E+01	-3.82E+01
18	-3.91E+01	-3.88E+01	-3.89E+01
19	-3.89E+01	-3.79E+01	-3.86E+01
20	-3.91E+01	-3.81E+01	-3.85E+01
21	-3.92E+01	-3.81E+01	-3.84E+01
22	-3.91E+01	-3.80E+01	-3.88E+01
23	-3.93E+01	-3.81E+01	
24	-3.79E+01	-3.72E+01	
Biased Statistics			
Average Biased	-3.89E+01	-3.80E+01	-3.84E+01
Std Dev Biased	8.37E-02	3.65E-01	3.81E-01
Ps90%/90% (+KTL) Biased	-3.87E+01	-3.70E+01	-3.74E+01
Ps90%/90% (-KTL) Biased	-3.91E+01	-3.90E+01	-3.95E+01
Un-Biased Statistics			
Average Un-Biased	-3.91E+01	-3.82E+01	-3.86E+01
Std Dev Un-Biased	1.10E-01	3.62E-01	1.98E-01
Ps90%/90% (+KTL) Un-Biased	-3.88E+01	-3.72E+01	-3.81E+01
Ps90%/90% (-KTL) Un-Biased	-3.94E+01	-3.92E+01	-3.92E+01
Specification MIN	-4.05E+01	-4.05E+01	-4.05E+01
Status	PASS	PASS	PASS
Specification MAX	-3.73E+01	-3.73E+01	-3.73E+01
Status	PASS	PASS	PASS



6.0. Summary / Conclusions

The low dose rate testing described in this final report was performed using the facilities at Aeroflex RAD's Longmire Laboratories in Colorado Springs, CO. The low dose rate source is a GB-150 irradiator modified to provide a panoramic exposure. The Co-60 rods are held in the base of the irradiator heavily shielded by lead. During the irradiation exposures the rod is raised by an electronic timer/controller and the exposure is performed in air. The dose rate for this irradiator in this configuration ranges from approximately 1mrad(Si)/s to a maximum of approximately 50rad(Si)/s, determined by the distance from the source.

The parametric data was obtained as "read and record" and all the raw data plus an attributes summary are contained in this report as well as in a separate Excel file. The attributes data contains the average, standard deviation and the average with the KTL values applied. The KTL value used in this work is 2.742 per MIL-HDBK-814 using one sided tolerance limits of 90/90 and a 5-piece sample size. The 90/90 KTL values were selected to match the statistical levels specified in the MIL-PRF-38535 sampling plan for the qualification of a radiation hardness assured (RHA) component. Note that the following criteria must be met for a device to pass the low dose rate test: following the radiation exposure each of the 5 pieces irradiated under electrical bias shall pass the specification value. The units irradiated without electrical bias and the KTL statistics are included in this report for reference only. If any of the 5 pieces irradiated under electrical bias exceed the device post radiation data sheet specification limits, then the lot could be logged as a failure.

Based on this criterion the RH5596 100MHz to 40GHz Linear-in-dB RMS Power Detector with 35dB Dynamic Range (from the lot traceability information provided on the first page of this test report) PASSED the low dose rate test to the maximum tested dose level of 100krad(Si) with all parameters remaining within their datasheet specifications.



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Appendix A: Photograph of a Sample Unit-Under-Test to Show Part Traceability



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Appendix B: Radiation Bias Connections and Absolute Maximum Ratings

LDR Radiation Biased Conditions: Provided by Linear Technology.

Pin	Function	Connection / Bias
1	VCC	To 3.3V via 1Ω resistor decoupled to GND with 100nF Capacitor
2	OUT	NC
3	FLTR	NC
4	GND	GND
5	GND	GND
6	RFIN	NC
7	GND	GND
8	EN	To 3.3V via 470Ω resistor decoupled to GND with 10pF Capacitor
9	PAD	GND

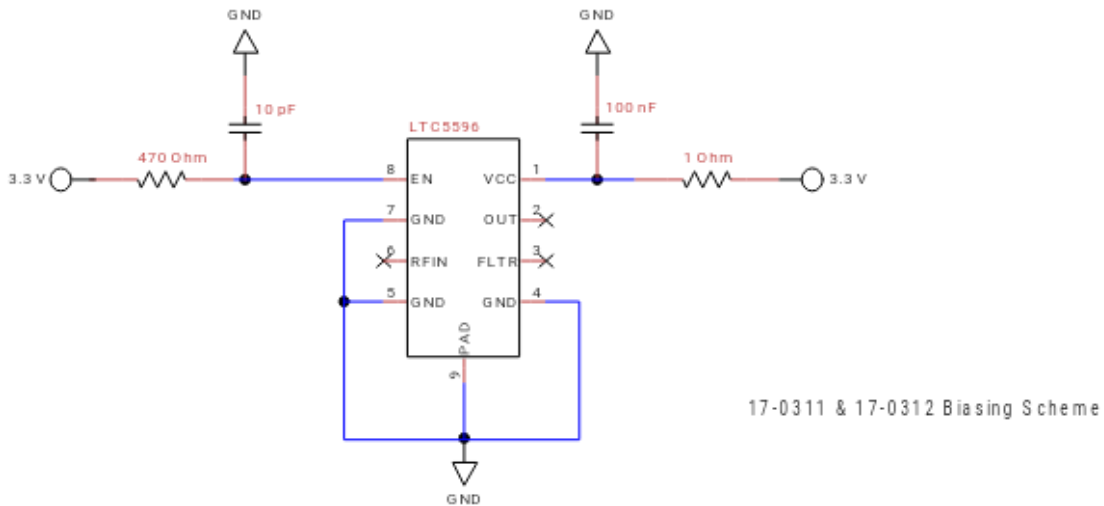


Figure B.1. Irradiation bias circuit.



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LDR Radiation Unbiased Conditions: All pins grounded.

Pin	Function	Connection / Bias
1	VCC	GND
2	OUT	GND
3	FLTR	GND
4	GND	GND
5	GND	GND
6	RFIN	GND
7	GND	GND
8	EN	GND
9	PAD	GND



Appendix C: Electrical Test Parameters and Conditions

The expected ranges of values as well as the measurement conditions are taken from Linear Technology RH5596 Datasheet. All electrical tests for this device were performed by Linear Technology. The measured parameters, pre-irradiation specifications and test conditions are shown in Tables C.1 and C.2.

Note that the testing and statistics used in this document are based on an “analysis of variables” technique, which relies on small sample sizes to qualify much larger lot sizes (see MIL-HDBK-814, p. 91 for a discussion of statistical treatments). Not all measured parameters are well suited to this approach due to inherent large variations. If necessary, larger samples sizes could be used to qualify these parameters using an “attributes” approach.



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Table C.1. Measured parameters and test conditions for the RH5596, 100MHz to 40GHz Linear-in-dB RMS Power Detector with 35dB Dynamic Range.

Parameter	Symbol	Test Conditions
Shutdown Current1 (A)	ICC_OFF1	EN=0.6V, VCC=3.6V
Active Supply Current1 (A)	ICC_ON1	EN=1.1V, VCC=3.6V
Shutdown Supply Current (A)	ICC_OFF2	EN=0.0V, VCC=3.3V
Active Supply Current (A)	ICC_ON2	EN=3.3V, VCC=3.3V
EN Input High Voltage (V)	EN_IIIH	EN=3.6V, VCC=3.6V
Output DC Voltage1 (V)	VOUT1	EN=1.1V, VCC=3.3V, RFIN=GND
Output DC Voltage2 (V)	VOUT2	PIN=10dB, EN=1.1V, VCC=3.3V, RFIN=2.14GHz
Output Voltage Droop (V)	DROOP_SINK	ISINK=25mA
Logarithmic Slope (V/dB)	SLOPE	RFIN=2.14GHz
Logarithmic Intercept (dB)	INTERCEPT	RFIN=2.14GHz



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Table C.2. Measured parameters and pre-irradiation specifications for the RH5596, 100MHz to 40GHz Linear-in-dB RMS Power Detector with 35dB Dynamic Range.

Parameter	Pre-Irradiation Specification	
	MIN	MAX
Shutdown Current1 (A)		5.00E-06
Active Supply Current1 (A)	2.50E-02	3.50E-02
Shutdown Supply Current (A)		5.00E-07
Active Supply Current (A)	2.50E-02	3.50E-02
EN Input High Voltage (V)	1.10E-00	
Output DC Voltage1 (V)		5.00E-03
Output DC Voltage2 (V)	1.15E-00	1.25E-00
Output Voltage Droop (V)	-3.50E-01	2.00E-02
Logarithmic Slope (V/dB)	2.80E-02	3.05E-02
Logarithmic Intercept (dB)	-4.05E+01	-3.73E+01



Appendix D: List of Figures Used in the Results Section (Section 5)

- 5.1. Shutdown Current1 (A) @ EN=0.6V, VCC=3.6V
- 5.2. Active Supply Current1 (A) @ EN=1.1V, VCC=3.6V
- 5.3. Shutdown Supply Current (A) @ EN=0.0V, VCC=3.3V
- 5.4. Active Supply Current (A) @ EN=3.3V, VCC=3.3V
- 5.5. EN Pin Input Current (A) @ EN=3.6V, VCC=3.6V
- 5.6. Output DC Voltage1 (V) @ EN=1.1V, VCC=3.3V,RFIN=GND
- 5.7. Output DC Voltage2 (V) @ PIN=10dB, EN=1.1V, VCC=3.3V, RFIN=2.14GHz
- 5.8. Output Voltage Droop (V) @ ISINK=25mA
- 5.9. Logarithmic Slope (V/dB) @ RFIN=2.14GHz
- 5.10. Logarithmic Intercept (dB) @ RFIN=2.14GHz