Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Enhanced Low Dose Rate Sensitivity (ELDRS) Radiation Testing of the RH1034MW Micropower Dual Reference for Linear Technology

Customer: Linear Technology, PO# 53101L

RAD Job Number: 09-289

Part Type Tested: Linear Technology RH1034-1.2 Micropower Dual Reference

Traceability Information: Fab lot# WD003263.1, Wafer# 2, Assembly Lot #488939.1. Information obtained from Linear Technology PO#53101L. Date code marking on the package is 0840A. See Appendix A for a photograph of the device and part markings.

Quantity of Units: 12 units total, 5 units for biased irradiation, 5 units for unbiased irradiation and 2 control units. Serial numbers 53 to 57 were biased during irradiation. Serial numbers 58 to 62 were unbiased during irradiation (all pins tied to ground). Serial numbers 73 and 74 were used as controls. See Appendix B for the radiation bias connection table.

External Traveler: None required

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

TID Dose Rate and Test Increments: 10mrad(Si)/s with readings at pre-irradiation, 10, 20, 30, and 50krad(Si).

TID Overtest and Post-Irradiation Anneal: No overtest. 168-hour 100°C anneal. The anneal shall be performed in the same electrical bias condition as the irradiations. Electrical measurements shall be made following the anneal.

TID Test Standard: MIL-STD-883G, Method 1019.7, Condition D

TID Electrical Test Conditions: Pre-irradiation, and within one hour following each radiation exposure.

Test Hardware: LTS2020 Tester, 2100 Family Board, 0600 Fixture, and RH1034 DUT Card.

Facility and Radiation Source: Radiation Assured Devices Longmire Laboratories, Colorado Springs, CO using the GB-150 low dose rate Co60 source. Dosimetry performed by CaF TLDs traceable to NIST. RAD's dosimetry has been audited by DSCC and RAD has been awarded Laboratory Suitability for MIL-STD-750 TM 1019.5.

Irradiation and Test Temperature: Ambient room temperature for irradiation and test of 24°C ± 6°C per MIL-STD-883G.

RLAT Result: PASSED. Units Passed to 50krad(Si) with all parameters remaining within their pre- and/or post-radiation specification limits including after application of the 90/90 KTL statistics

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

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 (0.6μm 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-883G TM 1019.7). 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-883G TM 1019.7 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-883 TM 1019.7 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-883G TM 1019.7 Condition D, we have performed an ELDRS test at 10mrad(Si)/s.

2.0. Radiation Test Apparatus

The ELDRS testing described in this final report was performed using the facilities at Radiation Assured Devices' Longmire Laboratories in Colorado Springs, CO. The ELDRS 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 as determined by the distance from the source. For the low dose rate ELDRS testing described in this report, the devices are placed approximately 2-meters from the Co-60 rods. The irradiator calibration is maintained by Radiation Assured Devices' Longmire Laboratories using thermoluminescent dosimeters (TLDs) traceable to the National Institute of Standards and Technology (NIST). Figure 2.1 shows a photograph of the Co-60 irradiator at RAD's Longmire Laboratory facility.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Figure 2.1. Radiation Assured Devices' 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.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

3.0. Radiation Test Conditions

The RH1034MW Micropower Dual Reference described in this final report was tested using two bias conditions, biased with a single 20V supply and all pins tied to ground, see Appendix B for details on biasing conditions. These bias circuits satisfy the requirements of MIL-STD-883G TM1019.7 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 50krad(Si) with incremental readings at 10, 20, 30 and 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 TID bias board was positioned in the Co-60 cell to provide the required minimum of 50rad(Si)/s and was located inside a lead-aluminum enclosure. The lead-aluminum enclosure is required under MIL-STD-883G TM1019.7 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 TLD 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 ±5%.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

4.0. Tested Parameters

The following parameters were tested during the course of this work:

1. 1.2V Reference: Reverse Breakdown Voltage, V_Z (V)
2. 1.2V Reference: Reverse Breakdown Voltage Change with Current, $\Delta V_Z / \Delta I_Z$ (V)
3. 1.2V Reference: Reverse Dynamic Impedance. R_Z (Ω)
4. 7V Reference: Reverse Breakdown Voltage, V_Z (V)
5. 7V Reference: Reverse Breakdown Voltage Change with Current, $\Delta V_Z / \Delta I_Z$ (V)

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 values used is 2.742 per MIL HDBK 814 using one sided tolerance limits of 90/90 and a 5-piece sample size. This survival probability/level of confidence is consistent with a 22-piece sample size and zero failures analyzed using a lot tolerance percent defective (LTPD) approach. Note that the following criteria must be met for a device to pass the ELDRS testing: following the radiation exposure the unit shall pass the specification value and the average value for the each device must pass the specification value when the KTL limits are applied. If either of these conditions is not satisfied following the radiation exposure, then the lot could be logged as an RLAT failure.

Further, MIL-STD-883G, TM 1019.7 Section 3.13.1.1 Characterization test to determine if a part exhibits ELDRS" states the following: Select a minimum random sample of 21 devices from a population representative of recent production runs. Smaller sample sizes may be used if agreed upon between the parties to the test. All of the selected devices shall have undergone appropriate elevated temperature reliability screens, e.g. burn-in and high temperature storage life. Divide the samples into four groups of 5 each and use the remaining part for a control. Perform pre-irradiation electrical characterization on all parts assuring that they meet the Group A electrical tests. Irradiate 5 samples under a 0 volt bias and another 5 under the irradiation bias given in the acquisition specification at 50-300 rad(Si)/s and room temperature. Irradiate 5 samples under a 0 volt bias and another 5 under irradiation bias given in the acquisition specification at < 10mrad(Si)/s and room temperature. Irradiate all samples to the same dose levels, including 0.5 and 1.0 times the anticipated specification dose, and repeat the electrical characterization on each part at each dose level. Post irradiation electrical measurements shall be performed per paragraph 3.10 where the low dose rate test is considered Condition D. Calculate the radiation induced change in each electrical parameter (Δpara) for each sample at each radiation level. Calculate the ratio of the median Δpara at low dose rate to the median Δpara at high dose rate for each irradiation bias group at each total dose level. If this ratio exceeds 1.5 for any of the most sensitive parameters then the part is considered to be ELDRS susceptible. This test does not apply to parameters which exhibit changes that are within experimental error or whose values

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

are below the pre-irradiation electrical specification limits at low dose rate at the specification dose.

Therefore, the data in this report can be analyzed along with the low dose rate report titled "Total Ionizing Dose (TID) Testing of the RH1034MW Micropower Dual Reference for Linear Technology" to demonstrate that these parts do not exhibit ELDRS as defined in the current test method.

5.0. ELDRS Test Results

Using the conditions stated above, the RH1034 Micropower Dual Reference (from the lot date code identified on the first page of this test report) passed the enhanced low dose rate sensitivity test to 50krad(Si) with all parameters remaining within their pre- and/or post-radiation specification limits, including after application of the KTL statistics. Figures 5.1 through 5.7 show plots of all the measured parameters versus total ionizing dose. In these 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 average of the data points after application of the KTL statistics on the sample irradiated in the biased condition while the shaded lines (solid or dashed) are the average of the data points after application of the 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. Similarly, tables 5.1 through 5.7 show the raw data, averages, standard deviation, +KTL statistics, -KTL statistics, specification limit and Pass/Fail condition for each parameter.

In addition to the radiation test results, the data plots and tables described above contain anneal data. The anneals are performed to better understand the underlying physical mechanisms responsible for radiation-induced parametric shifts and are not part of the criteria used to establish whether or not the lot passes or fails the RLAT. In all cases the parts either improved or exhibited no change during the anneal.

As seen clearly in these figures, the pre- and post-irradiation data are well within the specification even after application of the KTL statistics and the control units, as expected, show no significant changes to any of the parameters throughout the course of the measurements. Therefore we can conclude that the observed degradation was due to the radiation exposure and not drift in the test equipment.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

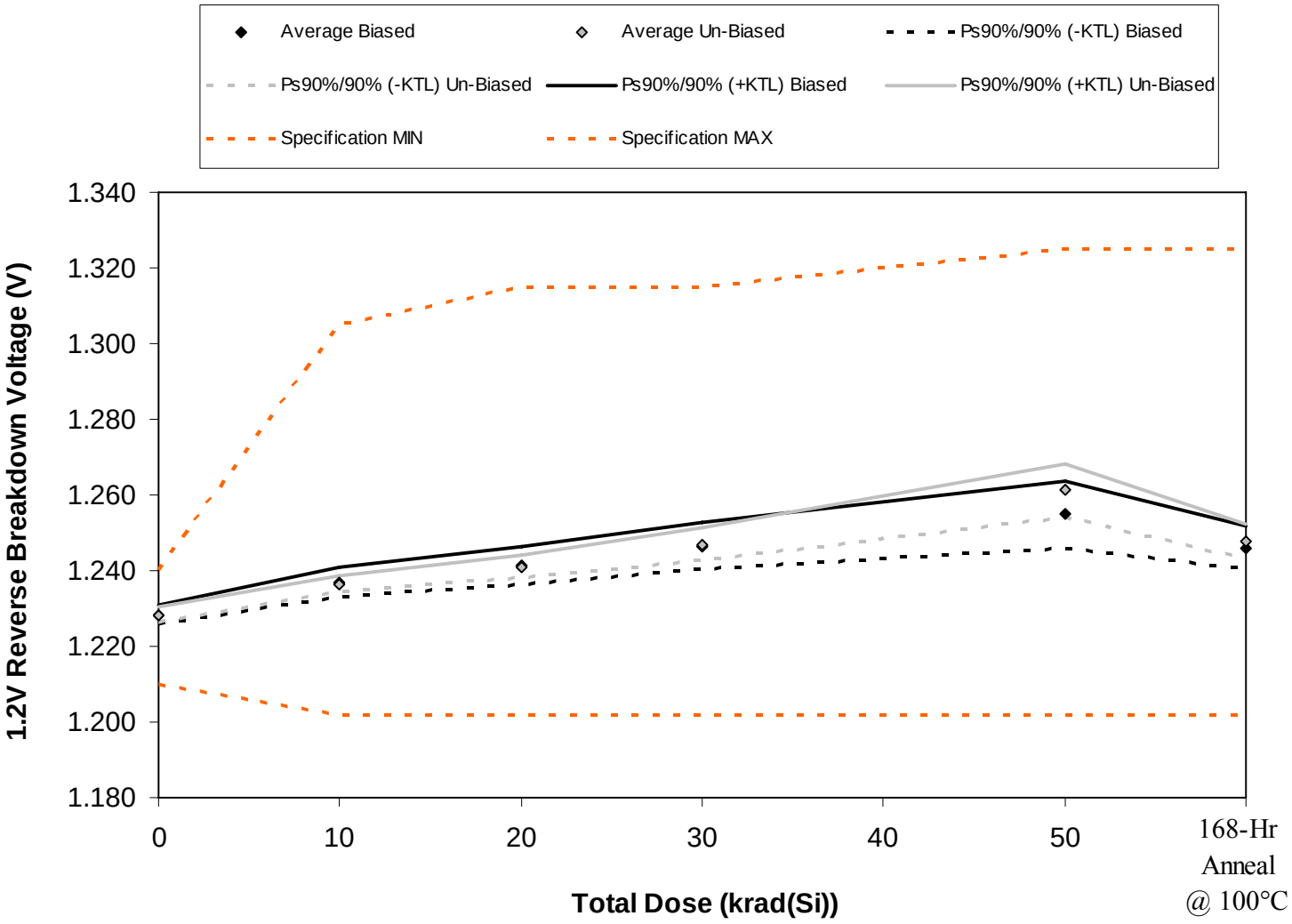


Figure 5.1. Plot of 1.2V Reverse Breakdown Voltage (V) versus total dose. The data show significant change with radiation, however the parameter remains within its post-radiation specification limits, including after application of the KTL statistics. The solid diamonds are the average of the measured 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 average of the data points after application of the KTL statistics on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the average of the data points after application of the 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.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Table 5.1. Raw data for 1.2V Reverse Breakdown Voltage (V) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

1.2V Reverse Breakdown Voltage (V)	Total Dose (krad(Si))					168-hr Anneal
Device	0	10	20	30	50	
53	1.2282	1.2366	1.2412	1.2459	1.2539	1.2455
54	1.2276	1.2351	1.2389	1.2431	1.2498	1.2431
55	1.2295	1.2386	1.2436	1.2489	1.2581	1.2485
56	1.2290	1.2379	1.2429	1.2482	1.2573	1.2476
57	1.2274	1.2361	1.2411	1.2462	1.2552	1.2456
58	1.2293	1.2371	1.2416	1.2473	1.2609	1.2479
59	1.2281	1.2358	1.2399	1.2453	1.2579	1.2457
60	1.2289	1.2374	1.2426	1.2490	1.2644	1.2498
61	1.2277	1.2356	1.2400	1.2458	1.2597	1.2467
62	1.2280	1.2365	1.2415	1.2478	1.2631	1.2487
73	1.2277	1.2278	1.2273	1.2276	1.2274	1.2278
74	1.2285	1.2286	1.2280	1.2284	1.2282	1.2285
Biased Statistics						
Average Biased	1.228	1.237	1.242	1.246	1.255	1.246
Std Dev Biased	8.99E-04	1.40E-03	1.83E-03	2.27E-03	3.28E-03	2.10E-03
Ps90%/90% (+KTL) Biased	1.231	1.241	1.247	1.253	1.264	1.252
Ps90%/90% (-KTL) Biased	1.226	1.233	1.237	1.240	1.246	1.240
Un-Biased Statistics						
Average Un-Biased	1.228	1.236	1.241	1.247	1.261	1.248
Std Dev Un-Biased	6.71E-04	7.85E-04	1.15E-03	1.50E-03	2.60E-03	1.61E-03
Ps90%/90% (+KTL) Un-Biased	1.230	1.239	1.244	1.251	1.268	1.252
Ps90%/90% (-KTL) Un-Biased	1.227	1.234	1.238	1.243	1.254	1.243
Specification MIN	1.2100	1.2020	1.2020	1.2020	1.2020	1.2020
Status	PASS	PASS	PASS	PASS	PASS	PASS
Specification MAX	1.2400	1.3050	1.3150	1.3150	1.3250	1.3250
Status	PASS	PASS	PASS	PASS	PASS	PASS

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

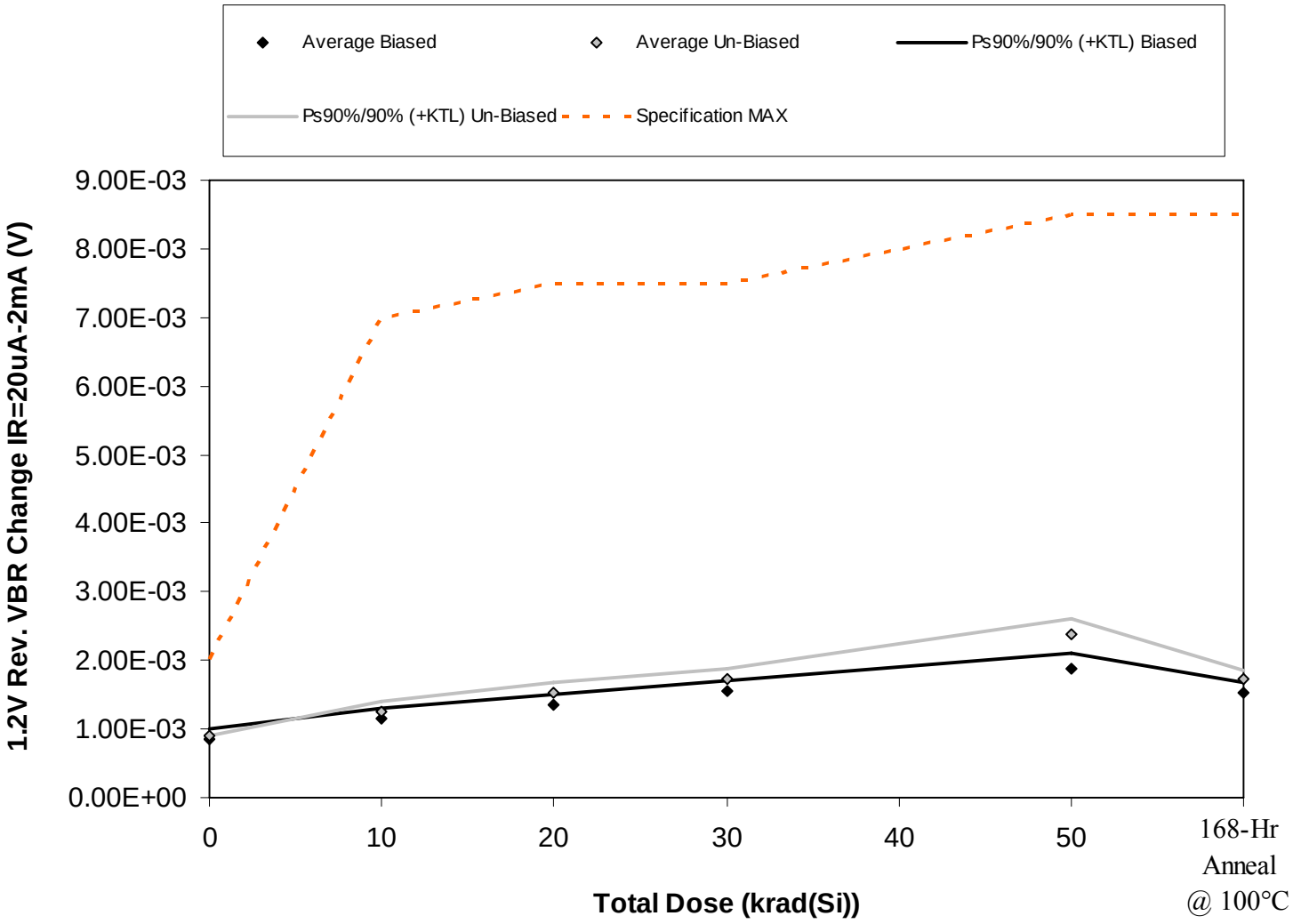


Figure 5.2. Plot of 1.2V Rev. VBR Change IR=20uA-2mA (V) versus total dose. The data show significant change with radiation, however the parameter remains within its post-radiation specification limits, including after application of the KTL statistics. The solid diamonds are the average of the measured 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 average of the data points after application of the KTL statistics on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the average of the data points after application of the 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.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Table 5.2. Raw data for 1.2V Rev. VBR Change IR=20uA-2mA (V) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

1.2V Rev. VBR Change IR=20uA-2mA (V)	Total Dose (krad(Si))					168-hr Anneal
Device	0	10	20	30	50	
53	9.00E-04	1.20E-03	1.40E-03	1.60E-03	2.00E-03	1.60E-03
54	9.00E-04	1.20E-03	1.30E-03	1.50E-03	1.80E-03	1.50E-03
55	9.00E-04	1.10E-03	1.30E-03	1.50E-03	1.80E-03	1.50E-03
56	8.00E-04	1.20E-03	1.40E-03	1.60E-03	1.90E-03	1.50E-03
57	8.00E-04	1.10E-03	1.40E-03	1.60E-03	1.90E-03	1.60E-03
58	9.00E-04	1.30E-03	1.60E-03	1.80E-03	2.40E-03	1.70E-03
59	9.00E-04	1.20E-03	1.50E-03	1.70E-03	2.30E-03	1.70E-03
60	9.00E-04	1.20E-03	1.50E-03	1.70E-03	2.30E-03	1.70E-03
61	9.00E-04	1.30E-03	1.50E-03	1.80E-03	2.50E-03	1.80E-03
62	9.00E-04	1.30E-03	1.60E-03	1.70E-03	2.40E-03	1.70E-03
73	9.00E-04	9.00E-04	9.00E-04	9.00E-04	9.00E-04	9.00E-04
74	1.00E-03	9.00E-04	1.00E-03	9.00E-04	9.00E-04	8.00E-04
Biased Statistics						
Average Biased	8.60E-04	1.16E-03	1.36E-03	1.56E-03	1.88E-03	1.54E-03
Std Dev Biased	5.48E-05	5.48E-05	5.48E-05	5.48E-05	8.37E-05	5.48E-05
Ps90%/90% (+KTL) Biased	1.01E-03	1.31E-03	1.51E-03	1.71E-03	2.11E-03	1.69E-03
Ps90%/90% (-KTL) Biased	7.10E-04	1.01E-03	1.21E-03	1.41E-03	1.65E-03	1.39E-03
Un-Biased Statistics						
Average Un-Biased	9.00E-04	1.26E-03	1.54E-03	1.74E-03	2.38E-03	1.72E-03
Std Dev Un-Biased	0.00E+00	5.48E-05	5.48E-05	5.48E-05	8.37E-05	4.47E-05
Ps90%/90% (+KTL) Un-Biased	9.00E-04	1.41E-03	1.69E-03	1.89E-03	2.61E-03	1.84E-03
Ps90%/90% (-KTL) Un-Biased	9.00E-04	1.11E-03	1.39E-03	1.59E-03	2.15E-03	1.60E-03
Specification MAX	2.00E-03	7.00E-03	7.50E-03	7.50E-03	8.50E-03	8.50E-03
Status	PASS	PASS	PASS	PASS	PASS	PASS

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

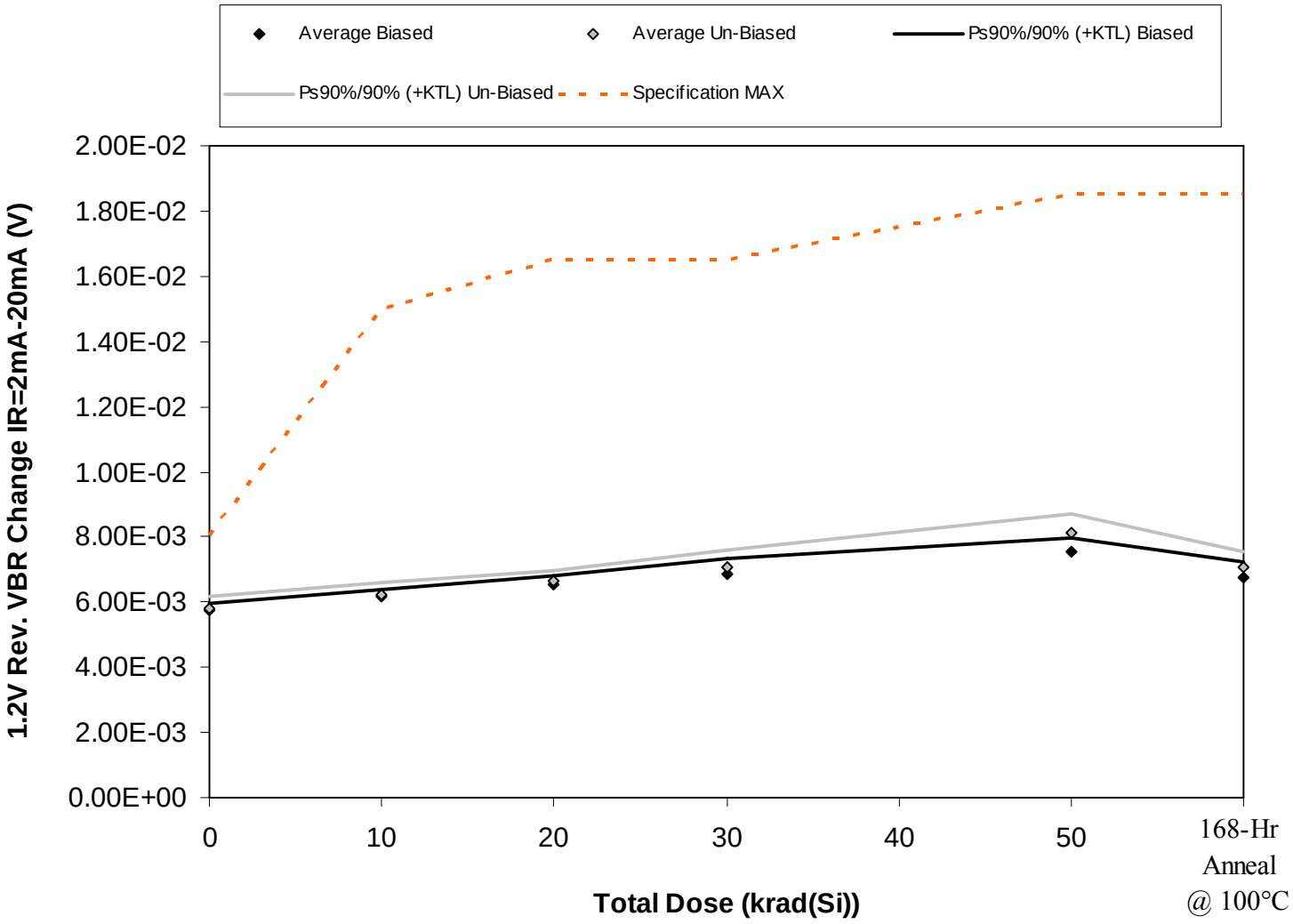


Figure 5.3. Plot of 1.2V Rev. VBR Change IR=2mA-20mA (V) versus total dose. The data show significant change with radiation, however the parameter remains within its post-radiation specification limits, including after application of the KTL statistics. The solid diamonds are the average of the measured 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 average of the data points after application of the KTL statistics on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the average of the data points after application of the 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.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Table 5.3. Raw data for 1.2V Rev. VBR Change IR=2mA-20mA (V) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

1.2V Rev. VBR Change IR=2mA-20mA (V)	Total Dose (krad(Si))					168-hr Anneal
Device	0	10	20	30	50	
53	5.70E-03	6.20E-03	6.50E-03	6.90E-03	7.50E-03	6.80E-03
54	5.80E-03	6.20E-03	6.60E-03	6.80E-03	7.40E-03	6.80E-03
55	5.60E-03	6.00E-03	6.40E-03	6.60E-03	7.40E-03	6.50E-03
56	5.80E-03	6.20E-03	6.60E-03	7.00E-03	7.70E-03	6.90E-03
57	5.80E-03	6.20E-03	6.60E-03	7.00E-03	7.70E-03	6.90E-03
58	5.80E-03	6.30E-03	6.60E-03	7.10E-03	8.10E-03	7.00E-03
59	5.70E-03	6.10E-03	6.60E-03	7.00E-03	8.00E-03	7.00E-03
60	5.70E-03	6.10E-03	6.50E-03	6.80E-03	7.90E-03	6.90E-03
61	5.90E-03	6.30E-03	6.80E-03	7.20E-03	8.40E-03	7.30E-03
62	6.00E-03	6.40E-03	6.70E-03	7.30E-03	8.30E-03	7.20E-03
73	5.90E-03	5.80E-03	5.80E-03	5.80E-03	5.80E-03	5.90E-03
74	5.90E-03	5.90E-03	5.80E-03	5.90E-03	5.90E-03	5.90E-03
Biased Statistics						
Average Biased	5.74E-03	6.16E-03	6.54E-03	6.86E-03	7.54E-03	6.78E-03
Std Dev Biased	8.94E-05	8.94E-05	8.94E-05	1.67E-04	1.52E-04	1.64E-04
Ps90%/90% (+KTL) Biased	5.99E-03	6.41E-03	6.79E-03	7.32E-03	7.96E-03	7.23E-03
Ps90%/90% (-KTL) Biased	5.49E-03	5.91E-03	6.29E-03	6.40E-03	7.12E-03	6.33E-03
Un-Biased Statistics						
Average Un-Biased	5.82E-03	6.24E-03	6.64E-03	7.08E-03	8.14E-03	7.08E-03
Std Dev Un-Biased	1.30E-04	1.34E-04	1.14E-04	1.92E-04	2.07E-04	1.64E-04
Ps90%/90% (+KTL) Un-Biased	6.18E-03	6.61E-03	6.95E-03	7.61E-03	8.71E-03	7.53E-03
Ps90%/90% (-KTL) Un-Biased	5.46E-03	5.87E-03	6.33E-03	6.55E-03	7.57E-03	6.63E-03
Specification MAX	8.00E-03	1.50E-02	1.65E-02	1.65E-02	1.85E-02	1.85E-02
Status	PASS	PASS	PASS	PASS	PASS	PASS

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

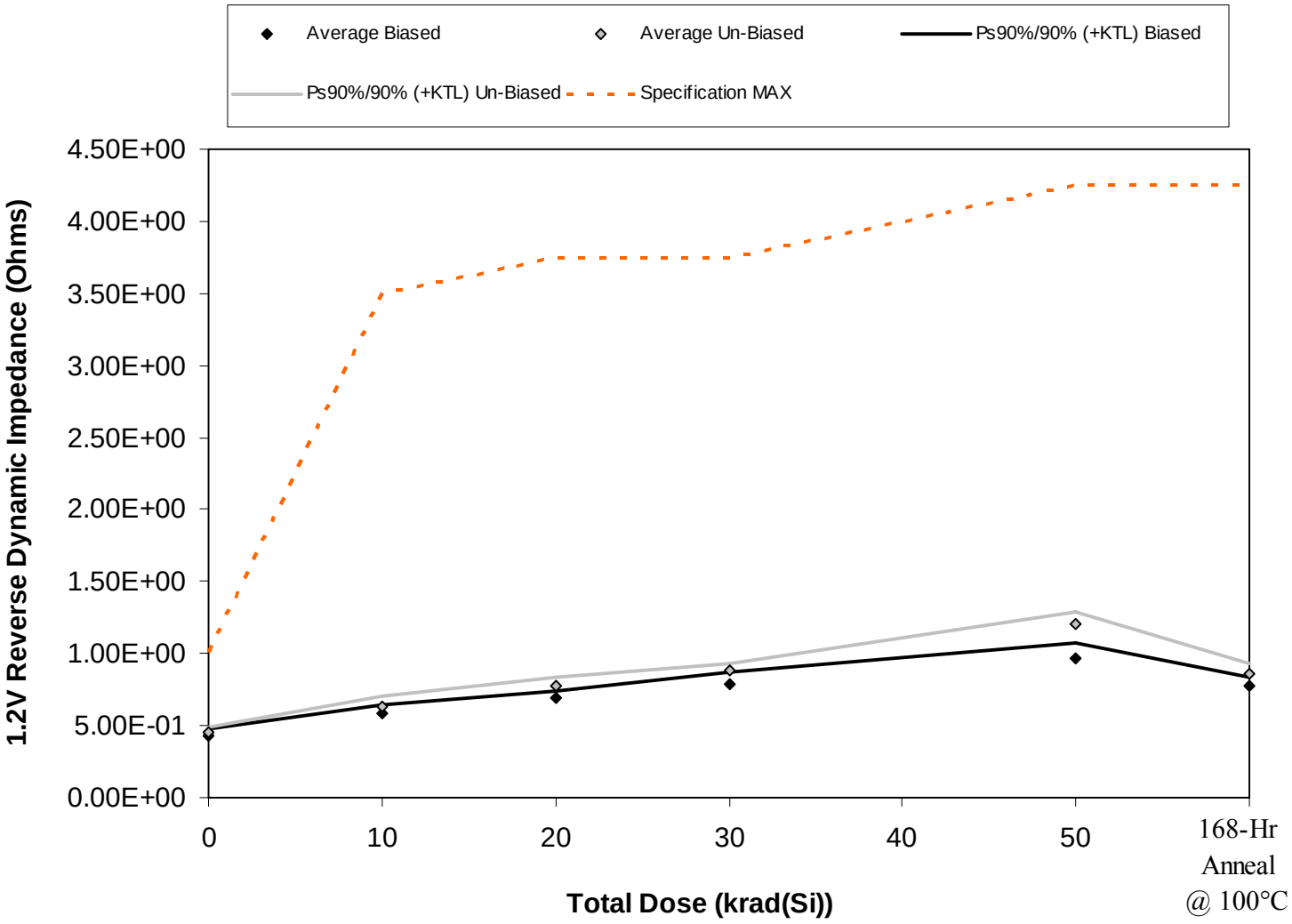


Figure 5.4. Plot of 1.2V Reverse Dynamic Impedance (Ohms) versus total dose. The data show significant change with radiation, however the parameter remains within its post-radiation specification limits, including after application of the KTL statistics. The solid diamonds are the average of the measured 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 average of the data points after application of the KTL statistics on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the average of the data points after application of the 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.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Table 5.4. Raw data for 1.2V Reverse Dynamic Impedance (Ohms) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

1.2V Reverse Dynamic Impedance (Ohms)	Total Dose (krad(Si))					168-hr Anneal
Device	0	10	20	30	50	
53	4.50E-01	6.03E-01	7.12E-01	7.94E-01	1.01E+00	8.03E-01
54	4.50E-01	5.81E-01	6.77E-01	7.40E-01	9.34E-01	7.49E-01
55	4.31E-01	5.62E-01	6.76E-01	7.63E-01	9.28E-01	7.50E-01
56	4.21E-01	6.18E-01	7.03E-01	8.09E-01	9.84E-01	7.69E-01
57	4.25E-01	5.77E-01	6.99E-01	8.07E-01	9.82E-01	7.89E-01
58	4.72E-01	6.68E-01	8.04E-01	8.94E-01	1.22E+00	8.53E-01
59	4.46E-01	6.06E-01	7.49E-01	8.75E-01	1.16E+00	8.55E-01
60	4.62E-01	5.94E-01	7.49E-01	8.69E-01	1.17E+00	8.34E-01
61	4.58E-01	6.35E-01	7.68E-01	9.07E-01	1.24E+00	9.03E-01
62	4.59E-01	6.37E-01	7.91E-01	8.78E-01	1.22E+00	8.61E-01
73	4.46E-01	4.62E-01	4.67E-01	4.63E-01	4.52E-01	4.53E-01
74	4.80E-01	4.69E-01	4.90E-01	4.69E-01	4.74E-01	4.28E-01
Biased Statistics						
Average Biased	4.35E-01	5.88E-01	6.93E-01	7.82E-01	9.68E-01	7.72E-01
Std Dev Biased	1.41E-02	2.24E-02	1.61E-02	3.03E-02	3.65E-02	2.39E-02
Ps90%/90% (+KTL) Biased	4.74E-01	6.50E-01	7.37E-01	8.66E-01	1.07E+00	8.38E-01
Ps90%/90% (-KTL) Biased	3.97E-01	5.27E-01	6.49E-01	6.99E-01	8.68E-01	7.06E-01
Un-Biased Statistics						
Average Un-Biased	4.59E-01	6.28E-01	7.72E-01	8.84E-01	1.20E+00	8.61E-01
Std Dev Un-Biased	9.27E-03	2.92E-02	2.47E-02	1.55E-02	3.37E-02	2.54E-02
Ps90%/90% (+KTL) Un-Biased	4.85E-01	7.08E-01	8.40E-01	9.27E-01	1.29E+00	9.31E-01
Ps90%/90% (-KTL) Un-Biased	4.34E-01	5.48E-01	7.04E-01	8.42E-01	1.11E+00	7.92E-01
Specification MAX	1.00E+00	3.50E+00	3.75E+00	3.75E+00	4.25E+00	4.25E+00
Status	PASS	PASS	PASS	PASS	PASS	PASS

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

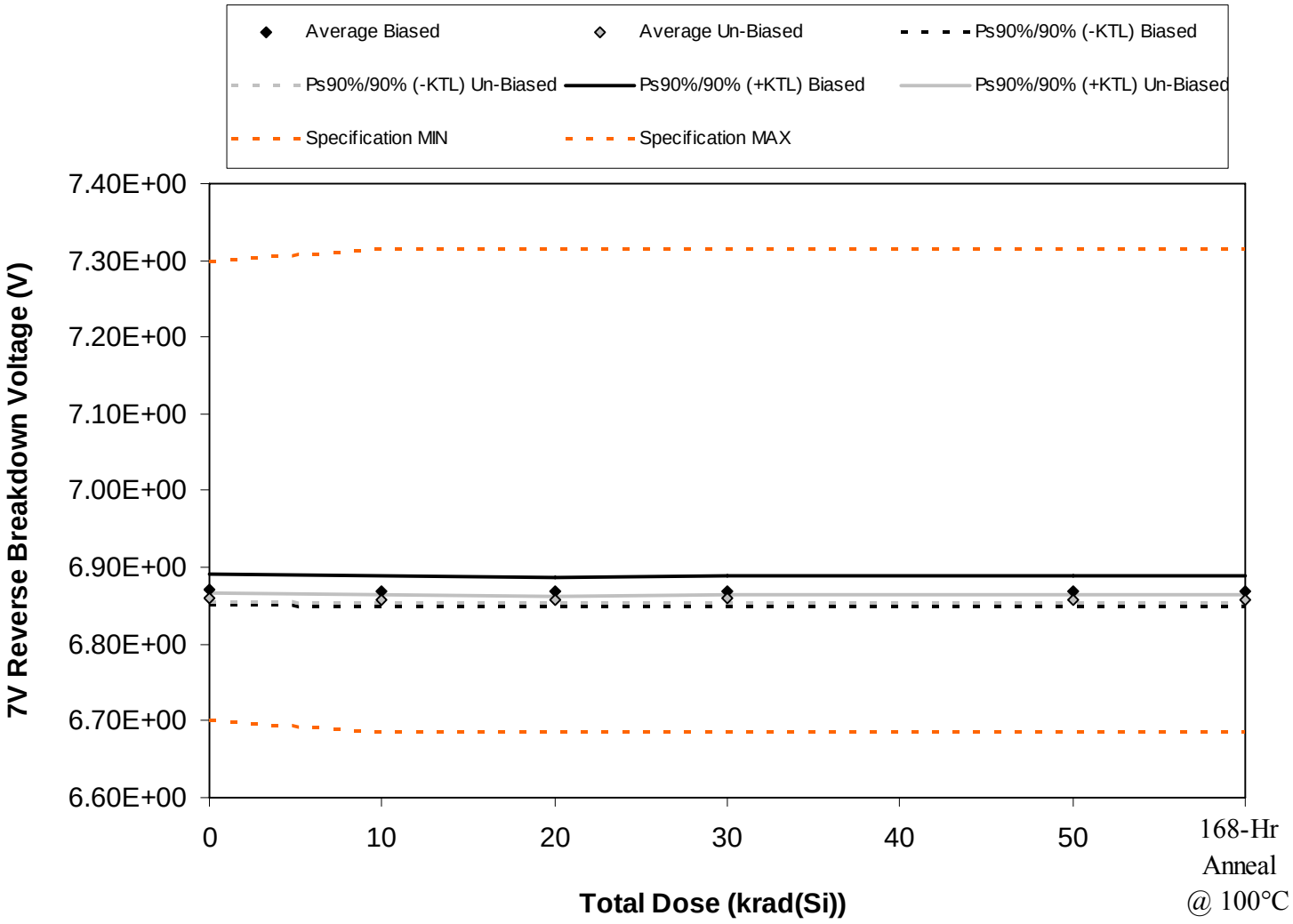


Figure 5.5. Plot of 7V Reverse Breakdown Voltage (V) versus total dose. The data show no significant change with total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the average of the data points after application of the KTL statistics on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the average of the data points after application of the 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.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Table 5.5. Raw data for 7V Reverse Breakdown Voltage (V) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

7V Reverse Breakdown Voltage (V)	Total Dose (krad(Si))					168-hr Anneal
Device	0	10	20	30	50	
53	6.860	6.859	6.858	6.859	6.858	6.859
54	6.870	6.869	6.868	6.869	6.869	6.869
55	6.873	6.871	6.870	6.872	6.871	6.871
56	6.868	6.867	6.866	6.867	6.866	6.867
57	6.880	6.879	6.878	6.879	6.878	6.878
58	6.858	6.856	6.855	6.857	6.856	6.856
59	6.859	6.857	6.856	6.858	6.857	6.857
60	6.862	6.860	6.860	6.861	6.860	6.860
61	6.860	6.858	6.857	6.858	6.858	6.858
62	6.863	6.861	6.860	6.861	6.861	6.861
73	6.862	6.860	6.860	6.861	6.860	6.858
74	6.850	6.848	6.847	6.849	6.848	6.863
Biased Statistics						
Average Biased	6.87E+00	6.87E+00	6.87E+00	6.87E+00	6.87E+00	6.87E+00
Std Dev Biased	7.33E-03	7.18E-03	7.22E-03	7.23E-03	7.26E-03	7.16E-03
Ps90%/90% (+KTL) Biased	6.89E+00	6.89E+00	6.89E+00	6.89E+00	6.89E+00	6.89E+00
Ps90%/90% (-KTL) Biased	6.85E+00	6.85E+00	6.85E+00	6.85E+00	6.85E+00	6.85E+00
Un-Biased Statistics						
Average Un-Biased	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00
Std Dev Un-Biased	2.09E-03	1.93E-03	1.99E-03	2.02E-03	2.03E-03	2.01E-03
Ps90%/90% (+KTL) Un-Biased	6.87E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00	6.86E+00
Ps90%/90% (-KTL) Un-Biased	6.85E+00	6.85E+00	6.85E+00	6.85E+00	6.85E+00	6.85E+00
Specification MIN	6.700	6.686	6.686	6.686	6.686	6.686
Status	PASS	PASS	PASS	PASS	PASS	PASS
Specification MAX	7.300	7.314	7.314	7.314	7.314	7.314
Status	PASS	PASS	PASS	PASS	PASS	PASS

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

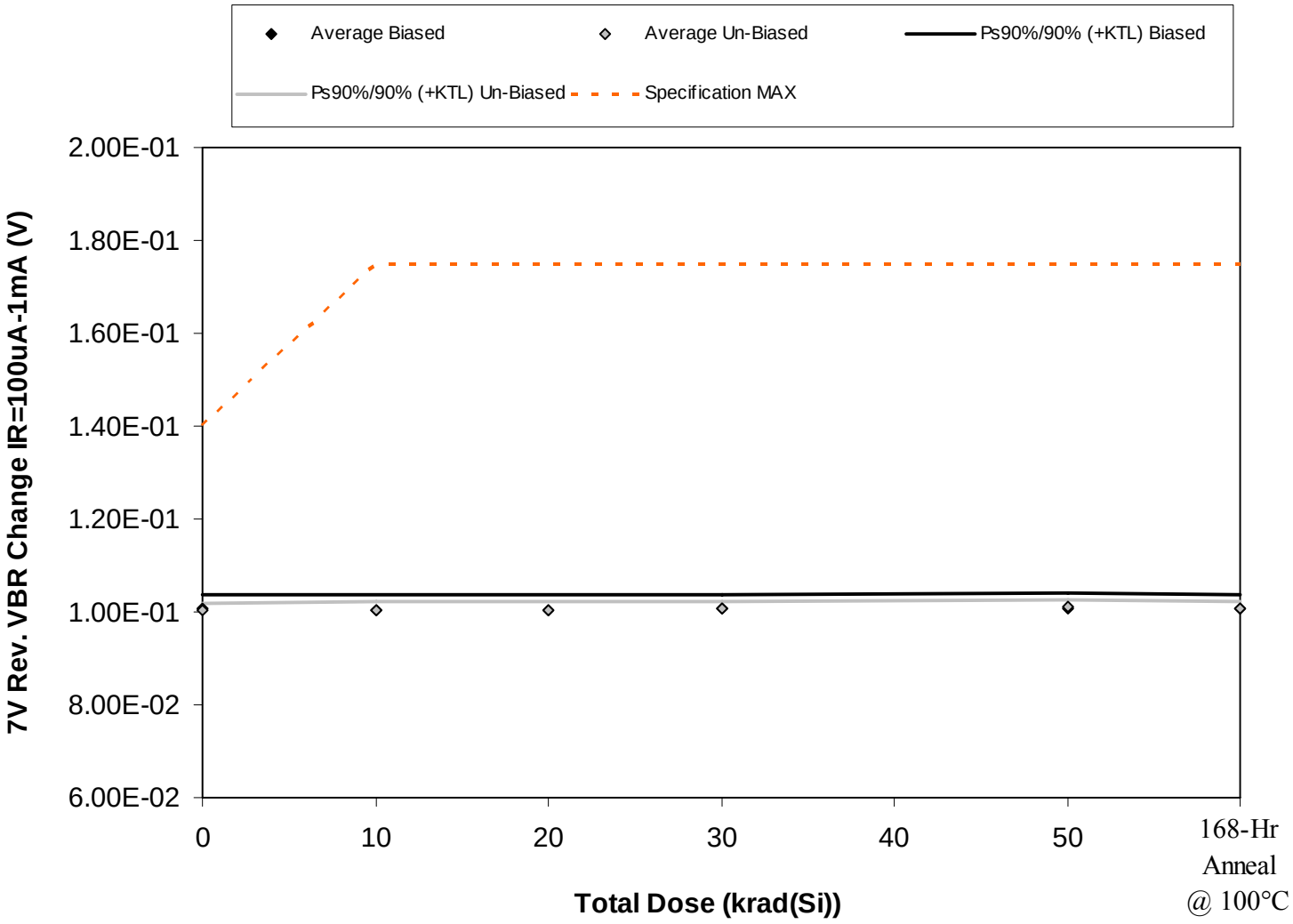


Figure 5.6. Plot of 7V Rev. VBR Change IR=100uA-1mA (V) versus total dose. The data show no significant change with total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the average of the data points after application of the KTL statistics on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the average of the data points after application of the 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.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Table 5.6. Raw data for 7V Rev. VBR Change IR=100uA-1mA (V) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

7V Rev. VBR Change IR=100uA-1mA (V)	Total Dose (krad(Si))					168-hr Anneal
Device	0	10	20	30	50	
53	9.97E-02	9.94E-02	9.93E-02	9.96E-02	9.99E-02	9.97E-02
54	1.00E-01	9.99E-02	1.00E-01	1.00E-01	1.00E-01	1.00E-01
55	1.03E-01	1.02E-01	1.02E-01	1.02E-01	1.03E-01	1.02E-01
56	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01
57	1.00E-01	9.98E-02	1.00E-01	1.00E-01	1.00E-01	1.00E-01
58	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01
59	1.01E-01	1.00E-01	1.00E-01	1.00E-01	1.01E-01	1.00E-01
60	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.02E-01	1.01E-01
61	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01
62	9.97E-02	9.95E-02	9.95E-02	1.00E-01	1.00E-01	9.99E-02
73	9.95E-02	9.90E-02	9.93E-02	9.95E-02	9.94E-02	9.25E-02
74	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	9.52E-02
Biased Statistics						
Average Biased	1.01E-01	1.00E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01
Std Dev Biased	1.11E-03	1.15E-03	1.14E-03	1.08E-03	1.11E-03	1.05E-03
Ps90%/90% (+KTL) Biased	1.04E-01	1.04E-01	1.04E-01	1.04E-01	1.04E-01	1.04E-01
Ps90%/90% (-KTL) Biased	9.77E-02	9.73E-02	9.74E-02	9.77E-02	9.78E-02	9.78E-02
Un-Biased Statistics						
Average Un-Biased	1.01E-01	1.00E-01	1.00E-01	1.01E-01	1.01E-01	1.01E-01
Std Dev Un-Biased	5.03E-04	6.30E-04	6.07E-04	5.40E-04	6.27E-04	5.40E-04
Ps90%/90% (+KTL) Un-Biased	1.02E-01	1.02E-01	1.02E-01	1.02E-01	1.03E-01	1.02E-01
Ps90%/90% (-KTL) Un-Biased	9.92E-02	9.87E-02	9.88E-02	9.92E-02	9.92E-02	9.91E-02
Specification MAX	1.40E-01	1.75E-01	1.75E-01	1.75E-01	1.75E-01	1.75E-01
Status	PASS	PASS	PASS	PASS	PASS	PASS

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

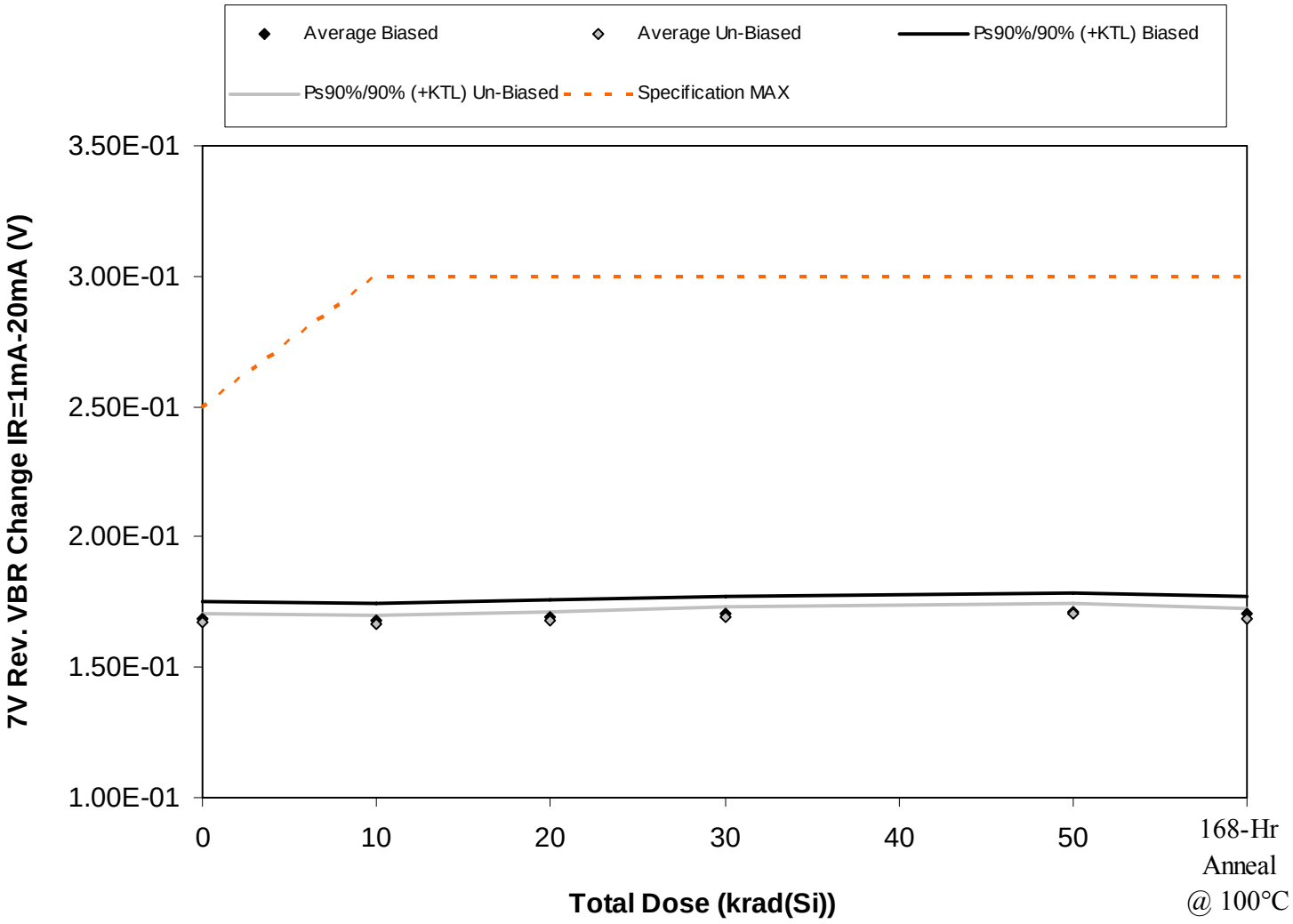


Figure 5.7. Plot of 7V Rev. VBR Change IR=1mA-20mA (V) versus total dose. The data show no significant change with total dose. The solid diamonds are the average of the measured data points for the samples irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the samples irradiated with all pins tied to ground. The black lines (solid and/or dashed) are the average of the data points after application of the KTL statistics on the samples irradiated under electrical bias while the gray lines (solid and/or dashed) are the average of the data points after application of the 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.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Table 5.7. Raw data for 7V Rev. VBR Change IR=1mA-20mA (V) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

7V Rev. VBR Change IR=1mA-20mA (V)	Total Dose (krad(Si))					168-hr Anneal
Device	0	10	20	30	50	
53	1.66E-01	1.65E-01	1.67E-01	1.68E-01	1.69E-01	1.68E-01
54	1.66E-01	1.66E-01	1.67E-01	1.68E-01	1.69E-01	1.68E-01
55	1.71E-01	1.70E-01	1.71E-01	1.73E-01	1.74E-01	1.73E-01
56	1.71E-01	1.71E-01	1.72E-01	1.73E-01	1.74E-01	1.73E-01
57	1.69E-01	1.68E-01	1.69E-01	1.70E-01	1.72E-01	1.70E-01
58	1.66E-01	1.66E-01	1.67E-01	1.68E-01	1.70E-01	1.68E-01
59	1.66E-01	1.66E-01	1.67E-01	1.68E-01	1.70E-01	1.68E-01
60	1.69E-01	1.69E-01	1.70E-01	1.71E-01	1.73E-01	1.71E-01
61	1.67E-01	1.67E-01	1.68E-01	1.69E-01	1.71E-01	1.69E-01
62	1.68E-01	1.68E-01	1.69E-01	1.70E-01	1.72E-01	1.70E-01
73	1.67E-01	1.65E-01	1.65E-01	1.66E-01	1.66E-01	1.61E-01
74	1.66E-01	1.63E-01	1.64E-01	1.64E-01	1.64E-01	1.62E-01
Biased Statistics						
Average Biased	1.68E-01	1.68E-01	1.69E-01	1.70E-01	1.72E-01	1.70E-01
Std Dev Biased	2.51E-03	2.48E-03	2.48E-03	2.58E-03	2.61E-03	2.48E-03
Ps90%/90% (+KTL) Biased	1.75E-01	1.75E-01	1.76E-01	1.77E-01	1.79E-01	1.77E-01
Ps90%/90% (-KTL) Biased	1.62E-01	1.61E-01	1.62E-01	1.63E-01	1.64E-01	1.63E-01
Un-Biased Statistics						
Average Un-Biased	1.67E-01	1.67E-01	1.68E-01	1.69E-01	1.71E-01	1.69E-01
Std Dev Un-Biased	1.25E-03	1.09E-03	1.21E-03	1.35E-03	1.31E-03	1.39E-03
Ps90%/90% (+KTL) Un-Biased	1.71E-01	1.70E-01	1.71E-01	1.73E-01	1.74E-01	1.73E-01
Ps90%/90% (-KTL) Un-Biased	1.64E-01	1.64E-01	1.65E-01	1.66E-01	1.67E-01	1.65E-01
Specification MAX	2.50E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01
Status	PASS	PASS	PASS	PASS	PASS	PASS

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

6.0. Summary / Conclusions

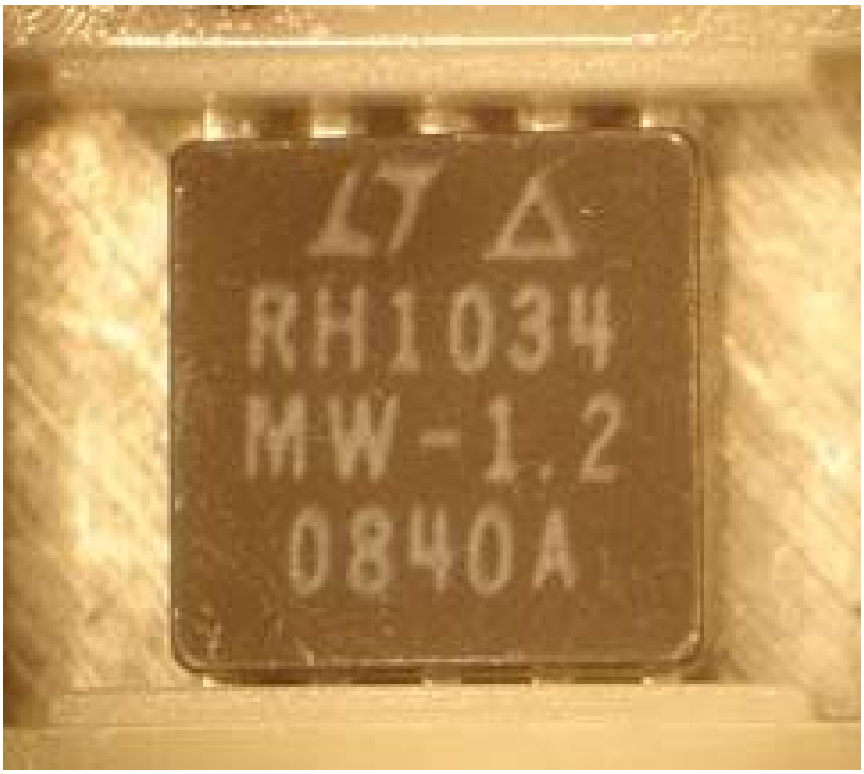
The high dose rate total ionizing dose testing described in this final report was performed using the facilities at Radiation Assured Devices' Longmire Laboratories in Colorado Springs, CO. The high dose rate total ionizing dose (TID) source is a JLSA 84-21 irradiator modified to provide a panoramic exposure. The dose rate for this irradiator in this configuration ranges from <1rad(Si)/s to a maximum of approximately 120rad(Si)/s, determined by the distance from the source. Samples of the RH1034MW Micropower Dual Reference described in this report were irradiated biased with a split 12V supply and unbiased (all leads tied to ground). The devices were irradiated to a maximum total ionizing dose level of 50krad(Si) with a pre-rad baseline reading as well as incremental readings at 10, 20, and 30krad(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. In addition, all units-under-test received a 24hr room temperature and168hr 100°C anneal, using the same bias conditions as the radiation exposure.

The parametric data was obtained as "read and record" and all the raw data plus an attributes summary were presented in this report. The attributes data contains the average, standard deviation and the average with the KTL values applied. The KTL value used was 2.742 per MIL HDBK 814 using one-sided tolerance limits of 90/90 and a 5-piece sample size. Note that the following criteria was used to determine the outcome of the testing: following the radiation exposure each parameter had to pass the specification value and the average value for each five-piece sample must pass the specification value when the KTL limits are applied. If these conditions were not satisfied following the radiation exposure, then the lot could be logged as an RLAT failure.

Based on the criteria stated above, the RH1034MW Micropower Dual Reference (from the lot date code identified on the first page of this test report) passed the ELDRS test to the highest level tested of 50krad(Si). All parameters remained within their pre- and/or post-radiation specification limits before and after application of the 90/90 KTL statistics.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Appendix A: Photograph of device-under-test to show part markings



Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Appendix B: TID Bias Connection Tables

(Extracted from LINEAR TECHNOLOGY CORPORATION RH1034-1.2 Datasheet)

Biased Samples:

Pin	Function	Bias
7	7V	To +20V via 14kΩ Resistor
8	1.2V	To +20V via 19.1kΩ Resistor
4	GND	GND

Unbiased Samples (All Pins Tied to Ground):

Pin	Function	Bias
7	7V	GND
8	1.2V	GND
4	GND	GND

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

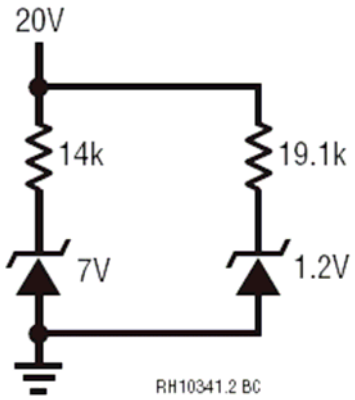


Figure B.1. Irradiation bias circuit for the units to be irradiated under electrical bias. This figure was extracted from the LINEAR TECHNOLOGY CORPORATION RH1034-1.2 Datasheet.

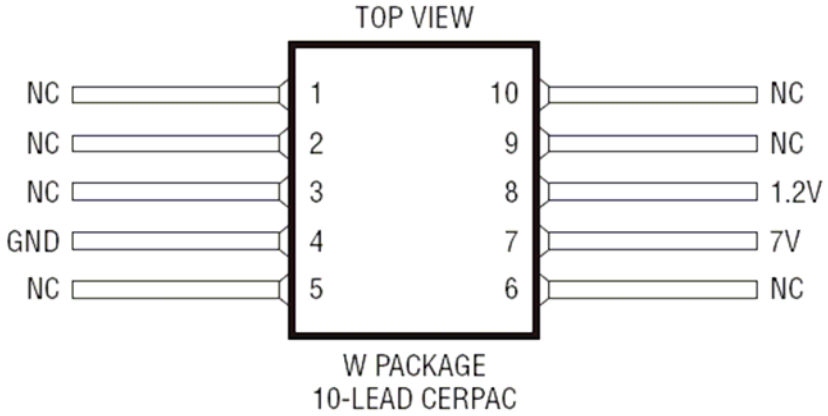


Figure B.2. W package drawing (for reference only). This figure was extracted from the LINEAR TECHNOLOGY CORPORATION RH1034-1.2 Datasheet.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Appendix C: Electrical Test Parameters and Conditions

All electrical tests for this device are performed on one of Radiation Assured Device's LTS2020 Test Systems. The LTS2020 Test System is a programmable parametric tester that provides parameter measurements for a variety of digital, analog and mixed signal products including voltage regulators, voltage comparators, D to A and A to D converters. The LTS2020 Test System achieves accuracy and sensitivity through the use of software self-calibration and an internal relay matrix with separate family boards and custom personality adapter boards. The tester uses this relay matrix to connect the required test circuits, select the appropriate voltage / current sources and establish the needed measurement loops for all the tests performed. The measured parameters and test conditions are shown in Table C.1.

A listing of the measurement precision/resolution for each parameter is shown in Table C.2. The precision/resolution values were obtained either from test data or from the DAC resolution of the LTS-2020. To generate the precision/resolution shown in Table C.2, one of the units-under-test was tested repetitively (a total of 10-times with re-insertion between tests) to obtain the average test value and standard deviation. Using this test data MIL-HDBK-814 90/90 KTL statistics were applied to the measured standard deviation to generate the final measurement range. This value encompasses the precision/resolution of all aspects of the test system, including the LTS2020 mainframe, family board, socket assembly and DUT board as well as insertion error. In some cases, the measurement resolution is limited by the internal DACs, which results in a measured standard deviation of zero. In these instances the precision/resolution will be reported back as the LSB of the DAC.

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). Unfortunately, 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.

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Table C.1. Measured parameters and test conditions for the RH1034MW. Unless otherwise noted the conditions were selected to match the post-irradiation specifications. See LINEAR TECHNOLOGY CORPORATION RH1034-1.2 Datasheet for the post irradiation test conditions and specifications.

1.2V Reference	
Parameter	**Test Conditions**
Reverse Breakdown Voltage, V_Z (V)	I_R=100µA
Reverse Breakdown Voltage Change with Current, $\Delta V_Z / \Delta I_Z$ (V)	I_R=20µA to 2mA I_R=2mA to 20mA
Reverse Dynamic Impedance. RZ (Ω)	I_R=20µA to 2mA
7V Reference	
Parameter	**Test Conditions**
Reverse Breakdown Voltage, V_Z (V)	I_R=100µA
Reverse Breakdown Voltage Change with Current, $\Delta V_Z / \Delta I_Z$ (V)	I_R=100µA to 1mA I_R=1mA to 20mA

Table C.2. Measured parameters, pre-irradiation specifications and measurement resolution for the RH1034MW.

1.2V Reference		
Measured Parameter	**Pre-Irradiation Specification**	**Measurement Precision/Resolution**
Reverse Breakdown Voltage, V_Z (V)	1.210 – 1.240V	±8.71E-05V
Reverse Breakdown Voltage Change with Current, $\Delta V_Z / \Delta I_Z$ (V)	2.0mV MAX 8.0mV MAX	±1.09E-04V
Reverse Dynamic Impedance. RZ (Ω)	1.0Ω MAX	±2.71E-02 Ω
7V Reference		
Measured Parameter	**Pre-Irradiation Specification**	**Measurement Precision/Resolution**
Reverse Breakdown Voltage, V_Z (V)	6.70 – 7.30V	±1.75E-04V
Reverse Breakdown Voltage Change with Current, $\Delta V_Z / \Delta I_Z$ (V)	140mV MAX 250mV MAX	±2.72-04V

Radiation Assured Devices
5017 N. 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Appendix D: List of Figures used in Section 5 (Test Results)