



***Enhanced Low Dose Rate Sensitivity (ELDRS) Radiation Testing of the
RH1011H Voltage Comparator for Linear Technology***

Customer: Linear Technology (PO49797L)

RAD Job Number: 08-131

Part Type Tested: Linear Technology RH1011H Voltage Comparator

Commercial Part Number: RH1011H

Traceability Information: Lot Date Code: 0703A, Fab Run # WP1075.1, W06 Can Assy Lot #417282.1

Quantity of Units: 11 units total, 5 units for biased irradiation, 5 units for unbiased irradiation and 1 control unit.

External Traveler: None

Pre-Irradiation Burn-In: Burn-in performed by Linear Technology prior to receipt of parts by RAD, Inc.

TID Dose Rate and Maximum Total Dose: 10mrad(Si)/s to 50krad(Si) total ionizing dose

TID Test Increments: Pre-Irradiation, 10krad(Si), 20krad(Si), 30krad(Si) and 50krad(Si)

TID Overtest and Post-Irradiation Anneal: No overtest. 24-hour room temperature anneal followed by a 168-hour 100°C anneal. Both anneals were performed in the same electrical bias condition as the irradiations. Electrical measurements shall be made following each anneal increment.

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 Programs: RH1011H.SRC

Hardware: LTS2020 Tester, 2101 Family Board, 0608 Fixture and DUT Board

TID Bias Conditions: Serial numbers 154-158 will be biased during irradiation, serial numbers 159, 160, 161, 163 and 174 will be unbiased during irradiation and serial number 162 will be used as the control.

Facility: Radiation Assured Devices Longmire Laboratories, Colorado Springs, CO

Radiation Source: Co60 (Gamma Beam 150)

Irradiation and Test Temperature: Ambient, room temperature

ELDRS Test Result: PASSED. All parts met datasheet specifications to 50krad(Si) with no substantial degradation to any measured parameter



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 μm 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.



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.



3.0. Radiation Test Conditions

The RH1011 voltage comparator described in this final report was tested using two bias conditions, biased with a split 12V supply and all pins tied to ground, see Appendix A for details on biasing conditions. These 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 ELDRS bias board was positioned in the Co-60 cell to provide the required 10mrad(Si)/s and was located inside a lead-aluminum box. The lead-aluminum box 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 10.0mrad(Si)/s with a precision of $\pm 5\%$.



4.0. Tested Parameters

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

1. Positive Supply Current
2. Negative Supply Current
3. Input Offset Voltage
4. Input Offset Current
5. + Input Bias Current
6. - Input Bias Current
7. Large Signal Voltage Gain
8. Common Mode Rejection Ratio
9. Strobe Current
10. Output Sat Voltage @ 8mA
11. Output Sat Voltage @ 50mA
12. Output Leakage Current

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 (Δ para) for each sample at each radiation level. Calculate the ratio of the median Δ para at low dose rate to the median Δ para 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 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 high dose rate report titled “Radiation Lot Acceptance Testing (RLAT) of the RH1011H Voltage Comparator 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 RH1011 devices passed the ELDRS test to 50krad(Si) with no significant degradation to any measured parameter. It should be noted that the open loop gain (AVOL) exceeded the specification post-irradiation (10 and 20krad(Si) read points) after application of the KTL statistics. This is primarily due to our ability to measure this parameters with high precision (See Appendix C, Table C.2). 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 (e.g. AVOL, as discussed above) where the device exhibits extreme sensitivity to input conditions, resulting in a very large standard deviation. If necessary, larger samples sizes could be used to qualify these parameters using an “attributes” approach. If a lot tolerance percent defective (LTPD) approach were used, then 22-pieces could be tested and if all units pass (without application of any statistics) then the lot is qualified to a 90/90 survival probability/level of confidence, the same level as achieved using the KTL statistics discussed in this report on a 5-piece sample size.

Figures 5.1 through 5.12 show plots of all the measured parameters versus total ionizing dose. 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 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. As seen clearly in these figures, the pre- and post-irradiation data are well within the specification even



after application of the KTL statistics (AVOL, as discussed above and input offset voltage where the average values with the KTL statistics applied are outside of the specification due to the large standard deviation of the sample population relative to the pre-irradiation V_{OS} limit of 1.5mV.). The control units, as expected, show no significant changes to any of the parameters. Therefore we can conclude that the small observed degradation was due to the radiation exposure.

Tables 5.1 through 5.12 show the raw data, averages, standard deviation, +KTL statistics, -KTL statistics, specification limit and Pass/Fail condition for each parameter.

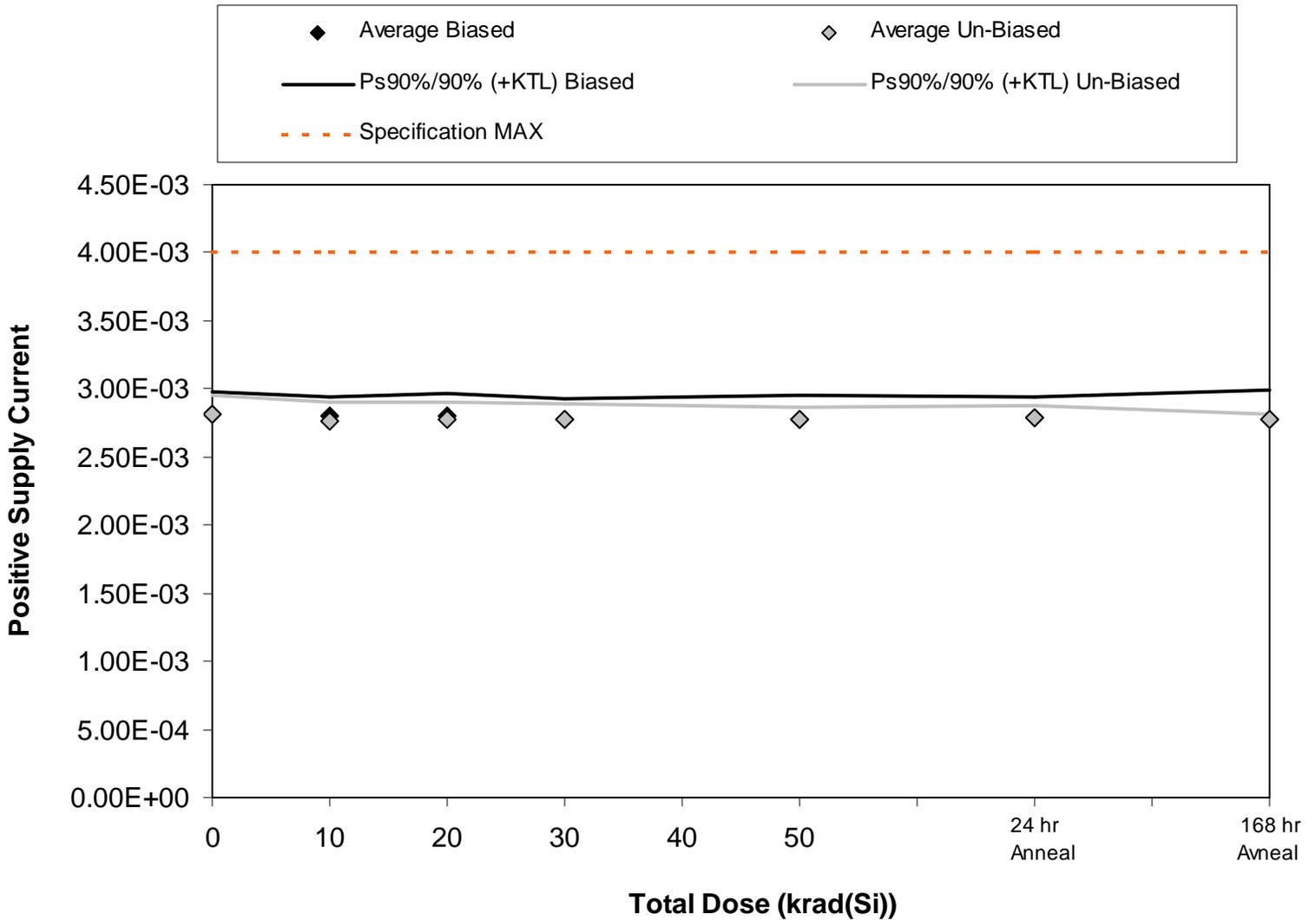


Figure 5.1. Plot of positive supply current versus total dose. The data shows no significant degradation with dose. The solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured data points for 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.



Table 5.1. Raw data for the positive supply current versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail)

Positive Supply Current	Total Dose (krad(Si))					24H	168H
	0	10	20	30	50	Anneal	Anneal
Device							
154	2.75E-03	2.73E-03	2.75E-03	2.72E-03	2.71E-03	2.73E-03	2.69E-03
155	2.82E-03	2.81E-03	2.79E-03	2.78E-03	2.78E-03	2.79E-03	2.80E-03
156	2.82E-03	2.83E-03	2.82E-03	2.79E-03	2.81E-03	2.80E-03	2.82E-03
157	2.91E-03	2.86E-03	2.89E-03	2.86E-03	2.87E-03	2.87E-03	2.88E-03
158	2.78E-03	2.77E-03	2.74E-03	2.76E-03	2.72E-03	2.74E-03	2.71E-03
159	2.85E-03	2.81E-03	2.80E-03	2.79E-03	2.80E-03	2.82E-03	2.78E-03
160	2.87E-03	2.82E-03	2.84E-03	2.83E-03	2.82E-03	2.82E-03	2.77E-03
161	2.82E-03	2.76E-03	2.78E-03	2.77E-03	2.75E-03	2.78E-03	2.78E-03
174	2.74E-03	2.70E-03	2.72E-03	2.72E-03	2.75E-03	2.75E-03	2.74E-03
163	2.79E-03	2.75E-03	2.76E-03	2.75E-03	2.75E-03	2.78E-03	2.78E-03
162	2.79E-03	2.76E-03	2.77E-03	2.75E-03	2.74E-03	2.78E-03	2.75E-03
Biased Statistics							
Average Biased	2.82E-03	2.80E-03	2.80E-03	2.78E-03	2.78E-03	2.79E-03	2.78E-03
Std Dev Biased	6.02E-05	5.10E-05	6.06E-05	5.12E-05	6.61E-05	5.59E-05	7.91E-05
Ps90%/90% (+KTL) Biased	2.98E-03	2.94E-03	2.96E-03	2.92E-03	2.96E-03	2.94E-03	3.00E-03
Ps90%/90% (-KTL) Biased	2.65E-03	2.66E-03	2.63E-03	2.64E-03	2.60E-03	2.63E-03	2.56E-03
Un-Biased Statistics							
Average Un-Biased	2.81E-03	2.77E-03	2.78E-03	2.77E-03	2.77E-03	2.79E-03	2.77E-03
Std Dev Un-Biased	5.13E-05	4.87E-05	4.47E-05	4.15E-05	3.36E-05	3.00E-05	1.73E-05
Ps90%/90% (+KTL) Un-Biased	2.95E-03	2.90E-03	2.90E-03	2.89E-03	2.87E-03	2.87E-03	2.82E-03
Ps90%/90% (-KTL) Un-Biased	2.67E-03	2.63E-03	2.66E-03	2.66E-03	2.68E-03	2.71E-03	2.72E-03
Specification MAX	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

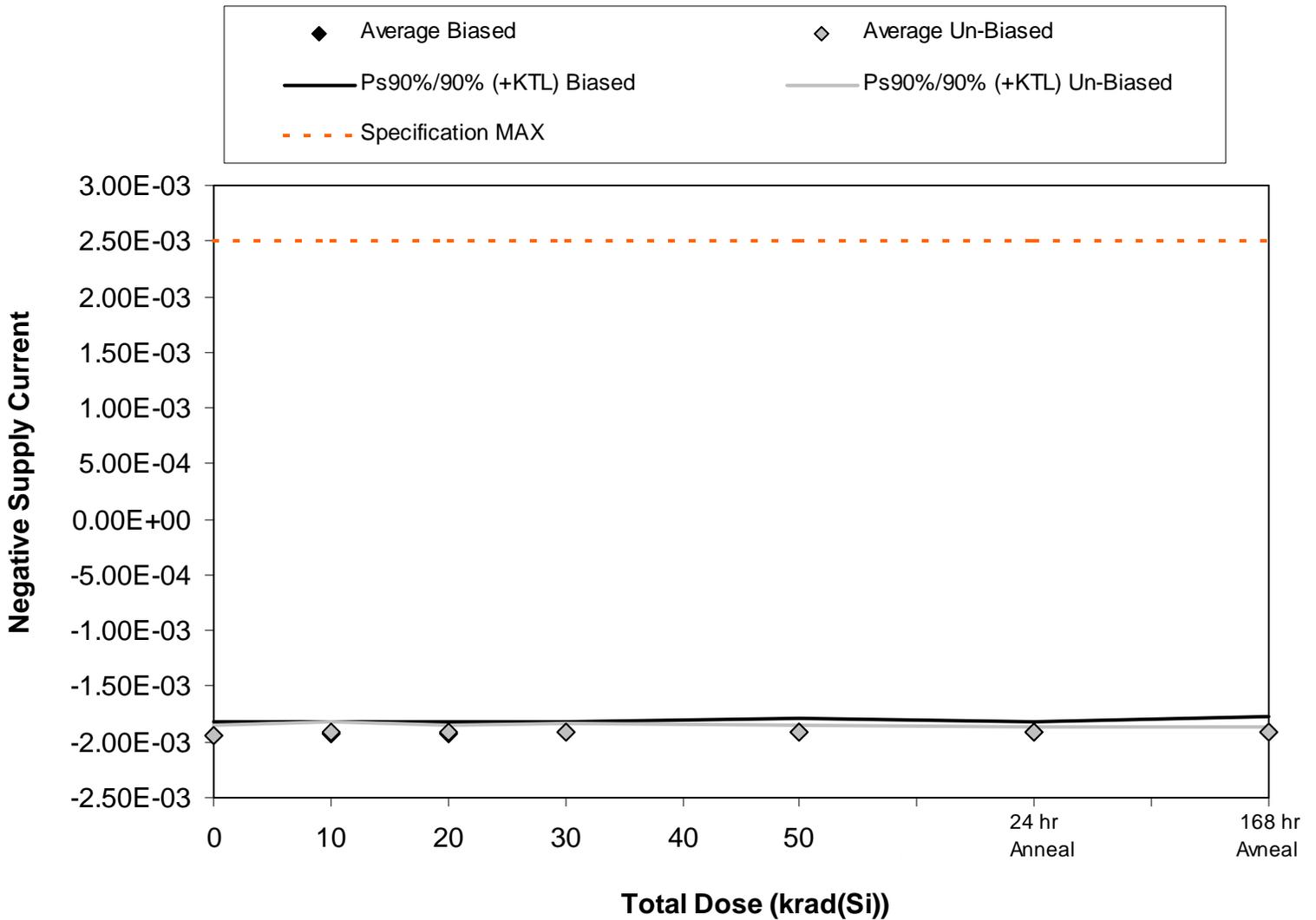


Figure 5.2. Plot of negative supply current versus total dose. The data shows no significant degradation with dose. The solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured data points for 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.



Table 5.2. Raw data for the negative supply current versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail)

Negative Supply Current Device	Total Dose (krad(Si))					24H Anneal	168H Anneal
	0	10	20	30	50		
154	-1.90E-03	-1.88E-03	-1.90E-03	-1.87E-03	-1.87E-03	-1.89E-03	-1.86E-03
155	-1.94E-03	-1.93E-03	-1.92E-03	-1.92E-03	-1.91E-03	-1.92E-03	-1.93E-03
156	-1.95E-03	-1.95E-03	-1.95E-03	-1.92E-03	-1.93E-03	-1.93E-03	-1.94E-03
157	-2.01E-03	-1.97E-03	-1.99E-03	-1.97E-03	-1.98E-03	-1.97E-03	-1.98E-03
158	-1.91E-03	-1.90E-03	-1.89E-03	-1.90E-03	-1.87E-03	-1.88E-03	-1.86E-03
159	-1.96E-03	-1.93E-03	-1.94E-03	-1.92E-03	-1.94E-03	-1.93E-03	-1.92E-03
160	-1.98E-03	-1.94E-03	-1.95E-03	-1.94E-03	-1.93E-03	-1.93E-03	-1.90E-03
161	-1.94E-03	-1.90E-03	-1.91E-03	-1.91E-03	-1.89E-03	-1.91E-03	-1.91E-03
174	-1.89E-03	-1.86E-03	-1.88E-03	-1.87E-03	-1.89E-03	-1.89E-03	-1.88E-03
163	-1.93E-03	-1.90E-03	-1.91E-03	-1.90E-03	-1.90E-03	-1.92E-03	-1.92E-03
162	-1.93E-03	-1.91E-03	-1.92E-03	-1.90E-03	-1.90E-03	-1.92E-03	-1.91E-03
Biased Statistics							
Average Biased	-1.94E-03	-1.93E-03	-1.93E-03	-1.92E-03	-1.91E-03	-1.92E-03	-1.91E-03
Std Dev Biased	4.32E-05	3.65E-05	4.06E-05	3.65E-05	4.60E-05	3.56E-05	5.27E-05
Ps90%/90% (+KTL) Biased	-1.82E-03	-1.83E-03	-1.82E-03	-1.82E-03	-1.79E-03	-1.82E-03	-1.77E-03
Ps90%/90% (-KTL) Biased	-2.06E-03	-2.03E-03	-2.04E-03	-2.02E-03	-2.04E-03	-2.02E-03	-2.06E-03
Un-Biased Statistics							
Average Un-Biased	-1.94E-03	-1.91E-03	-1.92E-03	-1.91E-03	-1.91E-03	-1.92E-03	-1.91E-03
Std Dev Un-Biased	3.39E-05	3.13E-05	2.77E-05	2.59E-05	2.35E-05	1.67E-05	1.67E-05
Ps90%/90% (+KTL) Un-Biased	-1.85E-03	-1.82E-03	-1.84E-03	-1.84E-03	-1.85E-03	-1.87E-03	-1.86E-03
Ps90%/90% (-KTL) Un-Biased	-2.03E-03	-1.99E-03	-1.99E-03	-1.98E-03	-1.97E-03	-1.96E-03	-1.95E-03
Specification MAX	2.50E-03	2.50E-03	2.50E-03	2.50E-03	2.50E-03	2.50E-03	2.50E-03
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

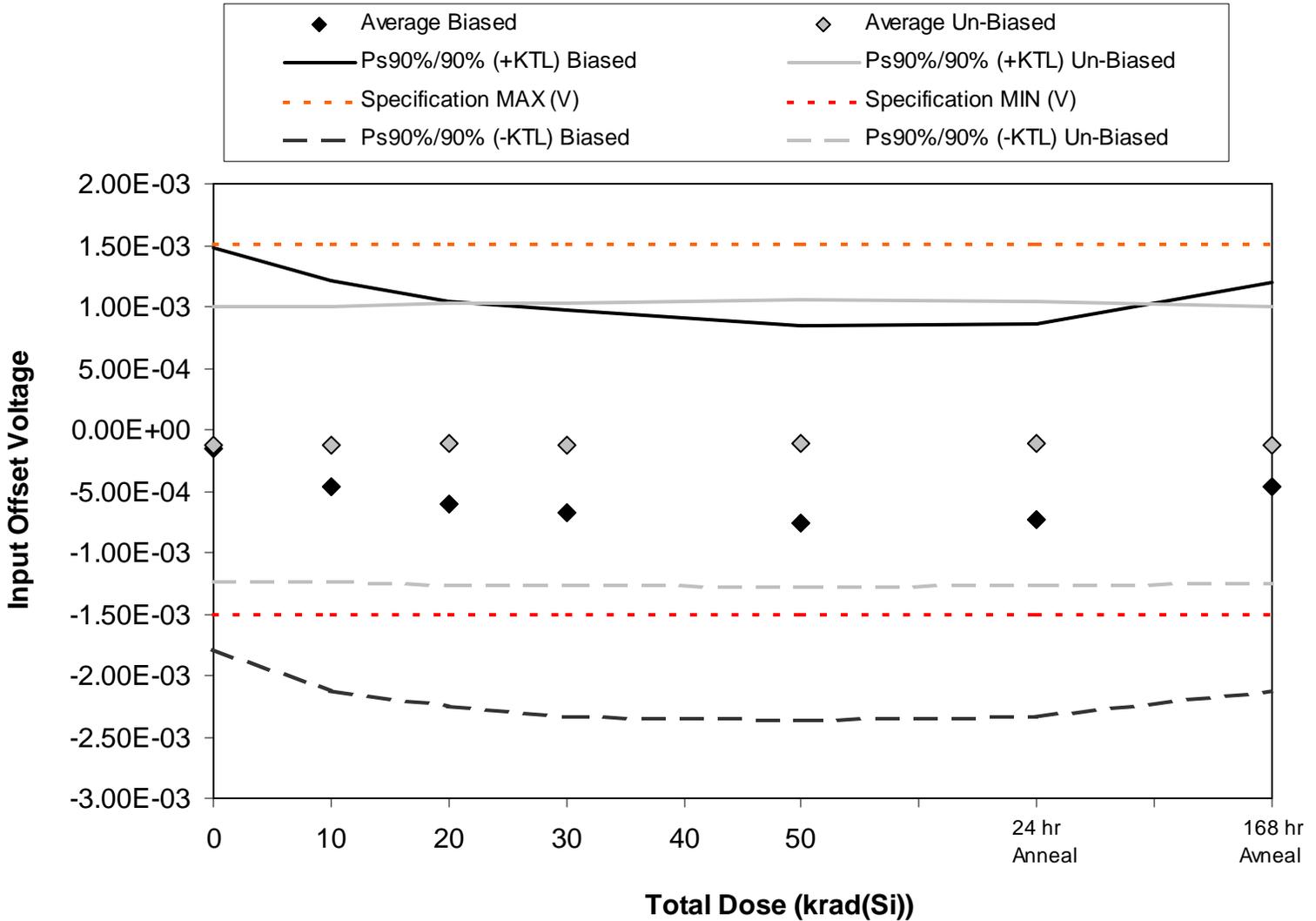


Figure 5.3. Plot of input offset voltage versus total dose. The data shows some degradation with dose for the biased samples, however none of the units fall below specification. The average values with the KTL statistics applied begin below specification due to the large standard deviation of the sample population relative to the pre-irradiation V_{OS} limit of 1.5mV. The manufacturer notes that pre-irradiation V_{OS} was aggressively specified at 1.5mV for marketing appeal. A more conservatively selected pre-irradiation limit of 3.0mV would have precluded this KTL fail. 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.



Table 5.3. Raw data for the input offset voltage versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail)

Input Offset Voltage	Total Dose (krad(Si))					24H	168H
	0	10	20	30	50	Anneal	Anneal
Device							
154	-8.80E-04	-1.18E-03	-1.31E-03	-1.38E-03	-1.41E-03	-1.38E-03	-1.19E-03
155	-3.70E-04	-6.50E-04	-7.90E-04	-8.60E-04	-9.20E-04	-8.90E-04	-6.90E-04
156	-1.50E-04	-4.60E-04	-5.90E-04	-6.40E-04	-6.90E-04	-6.80E-04	-4.70E-04
157	7.70E-04	5.00E-04	3.50E-04	2.80E-04	1.80E-04	2.00E-04	4.80E-04
158	-1.40E-04	-5.10E-04	-6.90E-04	-7.90E-04	-9.70E-04	-9.30E-04	-4.40E-04
159	-2.50E-04	-2.60E-04	-2.70E-04	-2.80E-04	-2.70E-04	-2.70E-04	-2.60E-04
160	2.30E-04	2.30E-04	2.50E-04	2.50E-04	2.60E-04	2.60E-04	2.10E-04
161	2.60E-04	2.60E-04	2.80E-04	2.70E-04	2.80E-04	2.80E-04	2.80E-04
174	-1.20E-04	-1.00E-04	-1.00E-04	-1.00E-04	-1.00E-04	-1.00E-04	-1.20E-04
163	-7.40E-04	-7.40E-04	-7.40E-04	-7.40E-04	-7.50E-04	-7.40E-04	-7.40E-04
162	-2.00E-04	-2.00E-04	-2.10E-04	-1.70E-04	-1.70E-04	-1.80E-04	-1.80E-04
Biased Statistics							
Average Biased	-1.54E-04	-4.60E-04	-6.06E-04	-6.78E-04	-7.62E-04	-7.36E-04	-4.62E-04
Std Dev Biased	5.97E-04	6.08E-04	6.02E-04	6.04E-04	5.88E-04	5.82E-04	6.06E-04
Ps90%/90% (+KTL) Biased	1.48E-03	1.21E-03	1.05E-03	9.77E-04	8.49E-04	8.60E-04	1.20E-03
Ps90%/90% (-KTL) Biased	-1.79E-03	-2.13E-03	-2.26E-03	-2.33E-03	-2.37E-03	-2.33E-03	-2.12E-03
Un-Biased Statistics							
Average Un-Biased	-1.24E-04	-1.22E-04	-1.16E-04	-1.20E-04	-1.16E-04	-1.14E-04	-1.26E-04
Std Dev Un-Biased	4.09E-04	4.10E-04	4.20E-04	4.18E-04	4.25E-04	4.22E-04	4.10E-04
Ps90%/90% (+KTL) Un-Biased	9.97E-04	1.00E-03	1.03E-03	1.03E-03	1.05E-03	1.04E-03	9.98E-04
Ps90%/90% (-KTL) Un-Biased	-1.24E-03	-1.25E-03	-1.27E-03	-1.27E-03	-1.28E-03	-1.27E-03	-1.25E-03
Specification MIN (V)	-1.50E-03	-1.50E-03	-1.50E-03	-1.50E-03	-1.50E-03	-1.50E-03	-1.50E-03
Status	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
Specification MAX (V)	1.50E-03	1.50E-03	1.50E-03	1.50E-03	1.50E-03	1.50E-03	1.50E-03
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

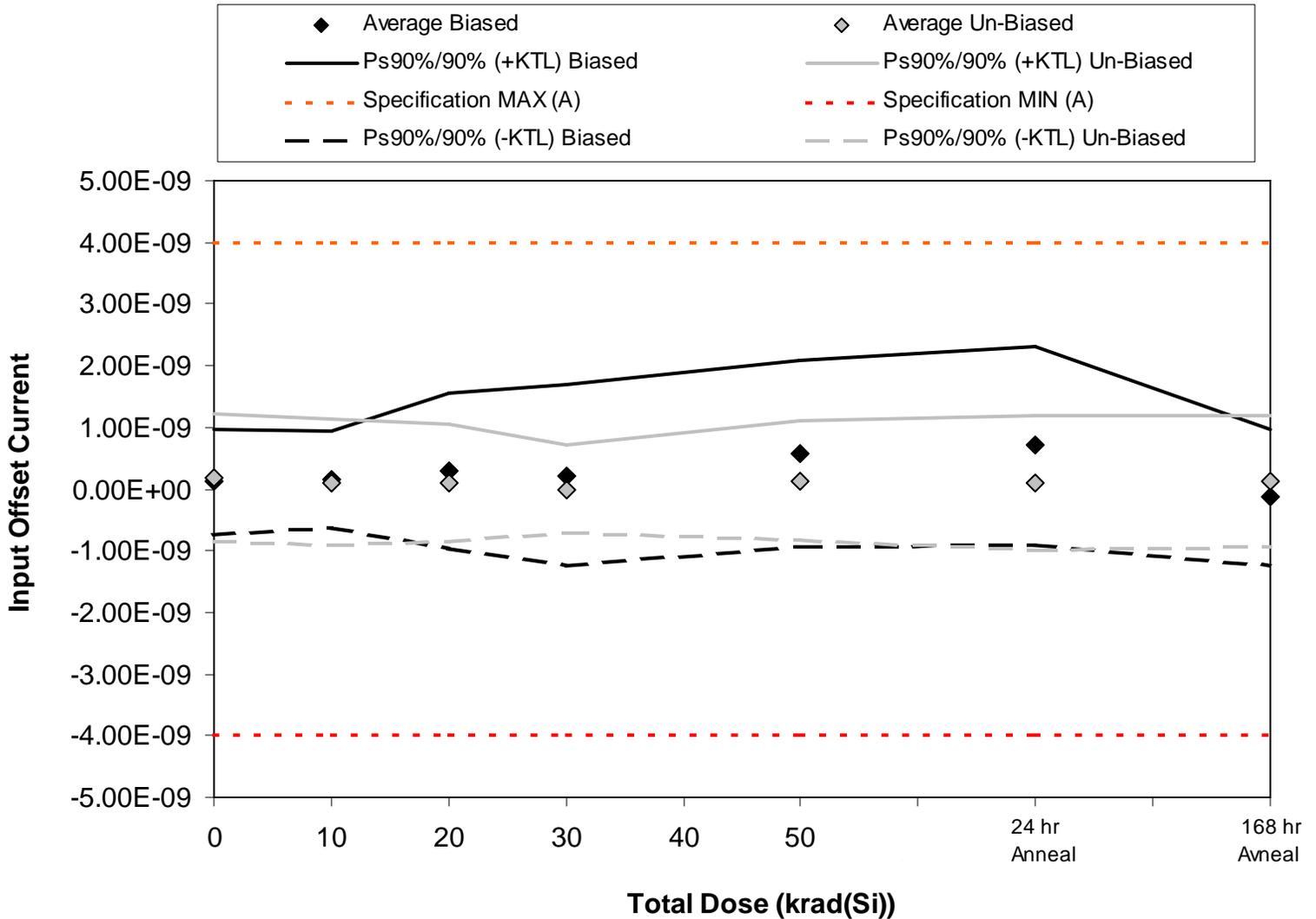


Figure 5.4. Plot of input offset current versus total dose. The data shows only a slight increase with dose for the samples irradiated under bias. The solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of 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.



Table 5.4. Raw data for input offset current versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail).

Input Offset Current	Total Dose (krad(Si))					24H	168H
	0	10	20	30	50	Anneal	Anneal
Device							
154	5.90E-10	6.20E-10	6.50E-10	9.00E-10	1.13E-09	1.35E-09	4.80E-10
155	-4.00E-11	1.10E-10	2.60E-10	3.40E-10	3.80E-10	5.60E-10	-2.40E-10
156	1.00E-10	6.00E-11	4.60E-10	1.70E-10	7.00E-10	8.10E-10	-7.00E-11
157	-2.40E-10	-1.50E-10	-4.80E-10	-5.90E-10	-2.90E-10	-2.10E-10	-6.20E-10
158	1.60E-10	1.30E-10	5.90E-10	2.90E-10	9.00E-10	1.03E-09	-2.40E-10
159	5.10E-10	4.90E-10	4.40E-10	1.20E-10	5.00E-10	4.30E-10	5.60E-10
160	2.00E-10	1.60E-10	-6.00E-11	-1.00E-10	-1.00E-11	-2.00E-11	1.00E-11
161	-4.50E-10	-4.80E-10	-4.10E-10	-4.20E-10	-3.60E-10	-5.00E-10	-4.80E-10
174	4.30E-10	3.30E-10	3.80E-10	2.30E-10	4.60E-10	4.90E-10	3.10E-10
163	2.10E-10	0.00E+00	1.30E-10	1.50E-10	1.00E-10	1.40E-10	1.80E-10
162	-1.80E-10	-1.70E-10	-2.20E-10	5.00E-11	8.00E-11	2.00E-11	2.00E-11
Biased Statistics							
Average Biased	1.14E-10	1.54E-10	2.96E-10	2.22E-10	5.64E-10	7.08E-10	-1.38E-10
Std Dev Biased	3.07E-10	2.83E-10	4.59E-10	5.34E-10	5.51E-10	5.90E-10	4.00E-10
Ps90%/90% (+KTL) Biased	9.57E-10	9.31E-10	1.55E-09	1.69E-09	2.08E-09	2.32E-09	9.59E-10
Ps90%/90% (-KTL) Biased	-7.29E-10	-6.23E-10	-9.62E-10	-1.24E-09	-9.47E-10	-9.09E-10	-1.23E-09
Un-Biased Statistics							
Average Un-Biased	1.80E-10	1.00E-10	9.60E-11	-4.00E-12	1.38E-10	1.08E-10	1.16E-10
Std Dev Un-Biased	3.77E-10	3.72E-10	3.47E-10	2.63E-10	3.56E-10	3.99E-10	3.89E-10
Ps90%/90% (+KTL) Un-Biased	1.21E-09	1.12E-09	1.05E-09	7.16E-10	1.11E-09	1.20E-09	1.18E-09
Ps90%/90% (-KTL) Un-Biased	-8.55E-10	-9.21E-10	-8.54E-10	-7.24E-10	-8.37E-10	-9.86E-10	-9.51E-10
Specification MIN (A)	-4.00E-09	-4.00E-09	-4.00E-09	-4.00E-09	-4.00E-09	-4.00E-09	-4.00E-09
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Specification MAX (A)	4.00E-09	4.00E-09	4.00E-09	4.00E-09	4.00E-09	4.00E-09	4.00E-09
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

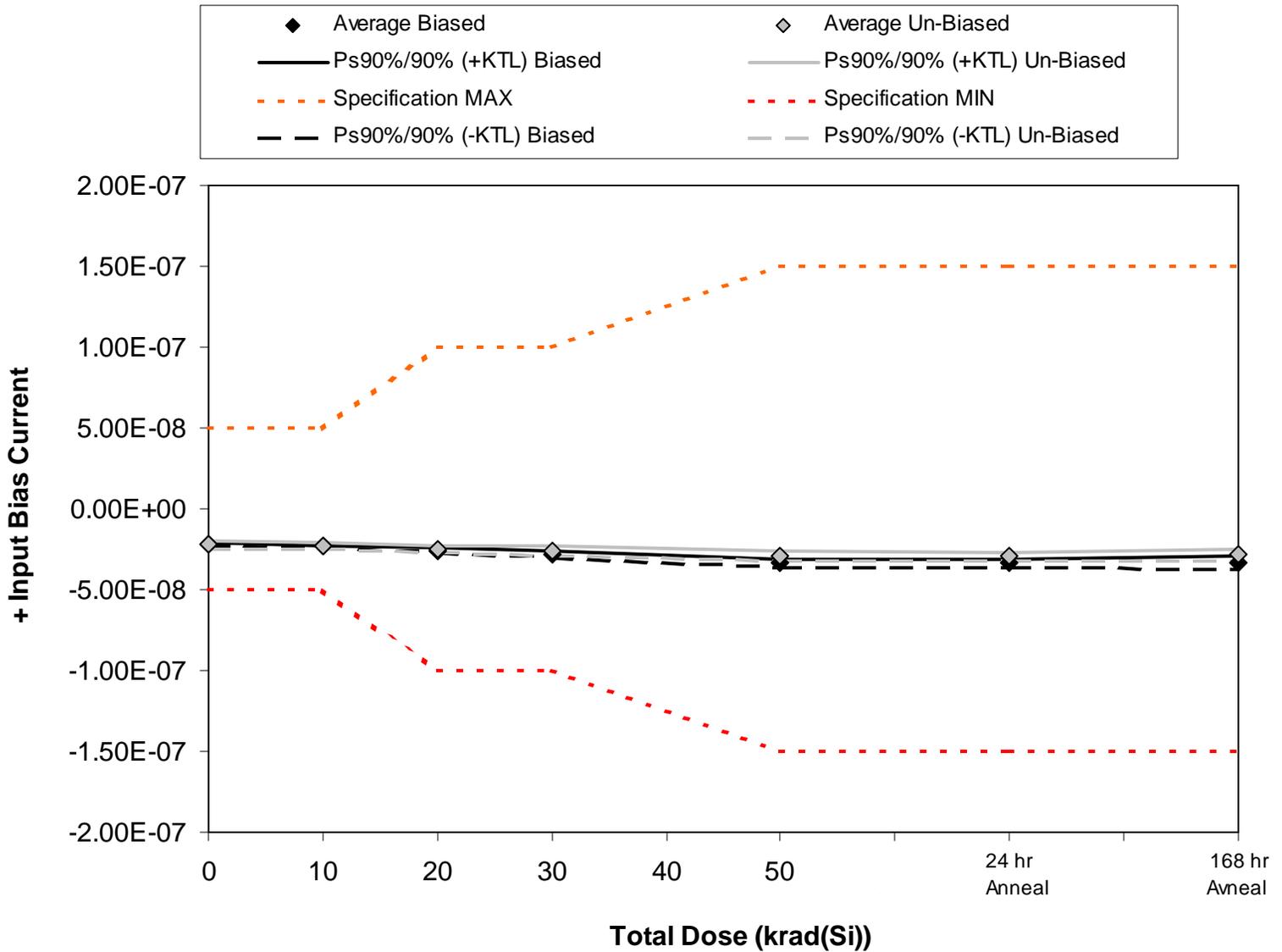


Figure 5.5. Plot of input bias current (non-inverting input) versus total dose. The data shows no significant degradation with dose. The solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured 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.



Table 5.5. Raw data for input bias current (non-inverting input) versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail).

+ Input Bias Current	Total Dose (krad(Si))					24H	168H
	0	10	20	30	50	Anneal	Anneal
Device							
154	-2.16E-08	-2.37E-08	-2.62E-08	-2.84E-08	-3.38E-08	-3.41E-08	-3.37E-08
155	-2.15E-08	-2.31E-08	-2.51E-08	-2.75E-08	-3.29E-08	-3.32E-08	-3.24E-08
156	-2.18E-08	-2.34E-08	-2.67E-08	-2.91E-08	-3.48E-08	-3.44E-08	-3.38E-08
157	-2.10E-08	-2.32E-08	-2.56E-08	-2.77E-08	-3.23E-08	-3.26E-08	-3.10E-08
158	-2.18E-08	-2.31E-08	-2.60E-08	-2.86E-08	-3.46E-08	-3.48E-08	-3.51E-08
159	-2.14E-08	-2.22E-08	-2.41E-08	-2.48E-08	-2.84E-08	-2.84E-08	-2.77E-08
160	-2.13E-08	-2.19E-08	-2.39E-08	-2.58E-08	-2.86E-08	-2.87E-08	-2.69E-08
161	-2.18E-08	-2.24E-08	-2.43E-08	-2.61E-08	-2.91E-08	-2.94E-08	-2.88E-08
174	-2.19E-08	-2.29E-08	-2.50E-08	-2.59E-08	-2.98E-08	-2.97E-08	-2.84E-08
163	-2.36E-08	-2.38E-08	-2.57E-08	-2.75E-08	-3.10E-08	-3.09E-08	-3.05E-08
162	-2.27E-08	-2.30E-08	-2.28E-08	-2.29E-08	-2.28E-08	-2.29E-08	-2.31E-08
Biased Statistics							
Average Biased	-2.15E-08	-2.33E-08	-2.59E-08	-2.83E-08	-3.37E-08	-3.38E-08	-3.32E-08
Std Dev Biased	3.54E-10	2.63E-10	6.06E-10	6.48E-10	1.07E-09	9.20E-10	1.54E-09
Ps90%/90% (+KTL) Biased	-2.06E-08	-2.26E-08	-2.42E-08	-2.65E-08	-3.08E-08	-3.13E-08	-2.90E-08
Ps90%/90% (-KTL) Biased	-2.25E-08	-2.40E-08	-2.76E-08	-3.00E-08	-3.66E-08	-3.63E-08	-3.74E-08
Un-Biased Statistics							
Average Un-Biased	-2.20E-08	-2.26E-08	-2.46E-08	-2.60E-08	-2.93E-08	-2.94E-08	-2.85E-08
Std Dev Un-Biased	9.15E-10	7.48E-10	7.62E-10	9.60E-10	1.05E-09	9.90E-10	1.36E-09
Ps90%/90% (+KTL) Un-Biased	-1.95E-08	-2.06E-08	-2.25E-08	-2.34E-08	-2.65E-08	-2.67E-08	-2.47E-08
Ps90%/90% (-KTL) Un-Biased	-2.45E-08	-2.47E-08	-2.67E-08	-2.87E-08	-3.22E-08	-3.21E-08	-3.22E-08
Specification MIN	-5.00E-08	-5.00E-08	-1.00E-07	-1.00E-07	-1.50E-07	-1.50E-07	-1.50E-07
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Specification MAX	5.00E-08	5.00E-08	1.00E-07	1.00E-07	1.50E-07	1.50E-07	1.50E-07
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

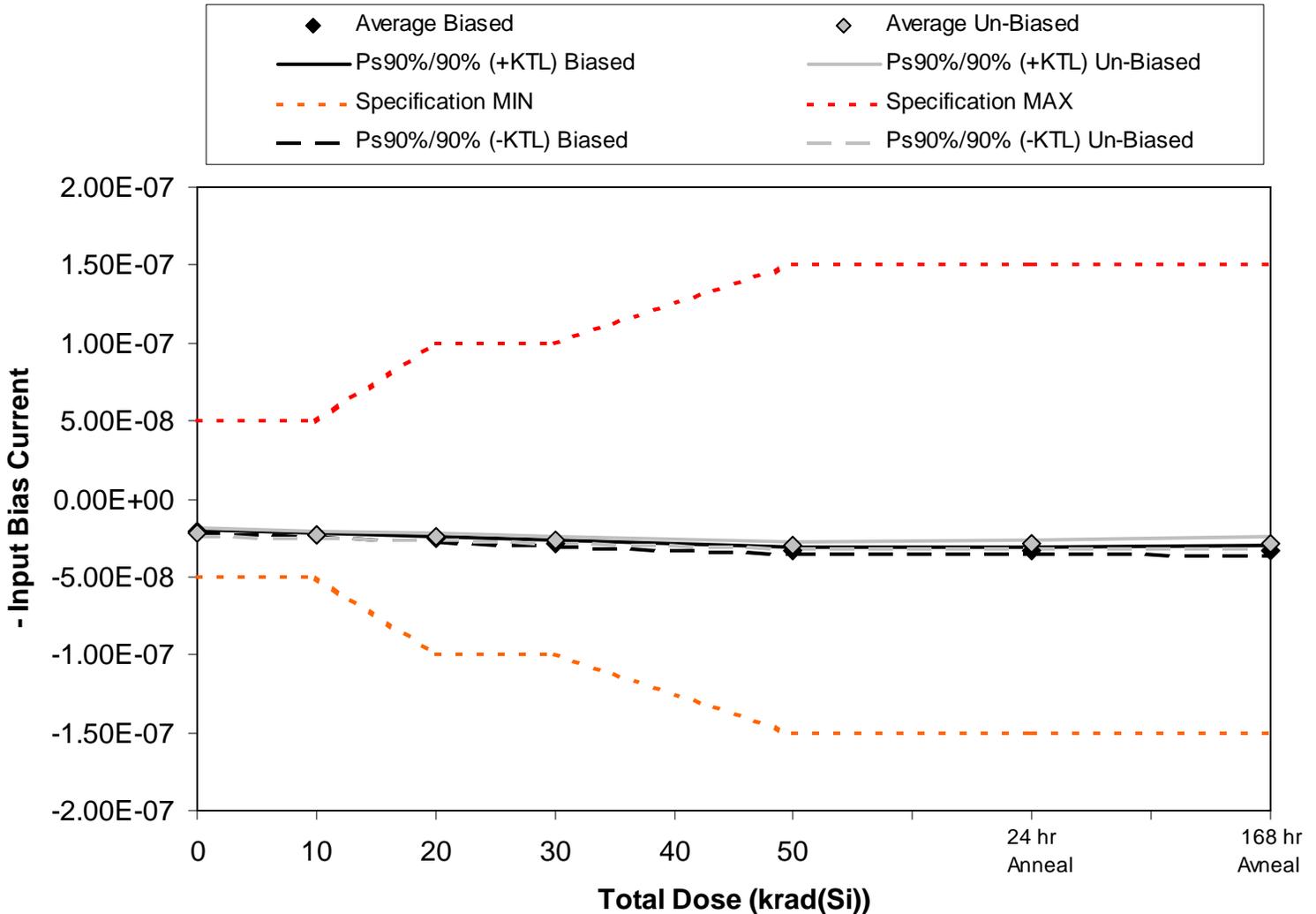


Figure 5.6. Plot of input bias current (inverting input) versus total dose. The data shows no significant degradation with dose. The solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured data 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.



Table 5.6. Raw data for input bias current (inverting input) versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail).

- Input Bias Current	Total Dose (krad(Si))					24H	168H
	0	10	20	30	50	Anneal	Anneal
Device							
154	-2.08E-08	-2.31E-08	-2.55E-08	-2.81E-08	-3.23E-08	-3.27E-08	-3.37E-08
155	-2.12E-08	-2.25E-08	-2.53E-08	-2.75E-08	-3.24E-08	-3.22E-08	-3.29E-08
156	-2.18E-08	-2.35E-08	-2.65E-08	-2.93E-08	-3.45E-08	-3.44E-08	-3.41E-08
157	-2.13E-08	-2.36E-08	-2.63E-08	-2.91E-08	-3.31E-08	-3.30E-08	-3.14E-08
158	-2.17E-08	-2.33E-08	-2.58E-08	-2.82E-08	-3.36E-08	-3.40E-08	-3.48E-08
159	-2.06E-08	-2.29E-08	-2.45E-08	-2.57E-08	-2.85E-08	-2.85E-08	-2.66E-08
160	-2.09E-08	-2.23E-08	-2.36E-08	-2.58E-08	-2.93E-08	-2.86E-08	-2.73E-08
161	-2.20E-08	-2.32E-08	-2.55E-08	-2.64E-08	-2.92E-08	-2.93E-08	-2.90E-08
174	-2.15E-08	-2.28E-08	-2.43E-08	-2.57E-08	-2.93E-08	-2.93E-08	-2.87E-08
163	-2.34E-08	-2.49E-08	-2.56E-08	-2.77E-08	-3.07E-08	-3.06E-08	-3.03E-08
162	-2.27E-08	-2.26E-08	-2.25E-08	-2.24E-08	-2.24E-08	-2.25E-08	-2.25E-08
Biased Statistics							
Average Biased	-2.14E-08	-2.32E-08	-2.59E-08	-2.84E-08	-3.32E-08	-3.32E-08	-3.34E-08
Std Dev Biased	4.28E-10	4.45E-10	4.94E-10	7.60E-10	8.88E-10	9.41E-10	1.30E-09
Ps90%/90% (+KTL) Biased	-2.02E-08	-2.20E-08	-2.45E-08	-2.64E-08	-3.07E-08	-3.07E-08	-2.98E-08
Ps90%/90% (-KTL) Biased	-2.25E-08	-2.44E-08	-2.72E-08	-3.05E-08	-3.56E-08	-3.58E-08	-3.69E-08
Un-Biased Statistics							
Average Un-Biased	-2.17E-08	-2.32E-08	-2.47E-08	-2.62E-08	-2.94E-08	-2.93E-08	-2.84E-08
Std Dev Un-Biased	1.09E-09	9.82E-10	8.47E-10	8.84E-10	7.96E-10	8.46E-10	1.48E-09
Ps90%/90% (+KTL) Un-Biased	-1.87E-08	-2.05E-08	-2.24E-08	-2.38E-08	-2.72E-08	-2.70E-08	-2.43E-08
Ps90%/90% (-KTL) Un-Biased	-2.47E-08	-2.59E-08	-2.70E-08	-2.87E-08	-3.16E-08	-3.16E-08	-3.24E-08
Specification MIN	-5.00E-08	-5.00E-08	-1.00E-07	-1.00E-07	-1.50E-07	-1.50E-07	-1.50E-07
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Specification MAX	5.00E-08	5.00E-08	1.00E-07	1.00E-07	1.50E-07	1.50E-07	1.50E-07
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

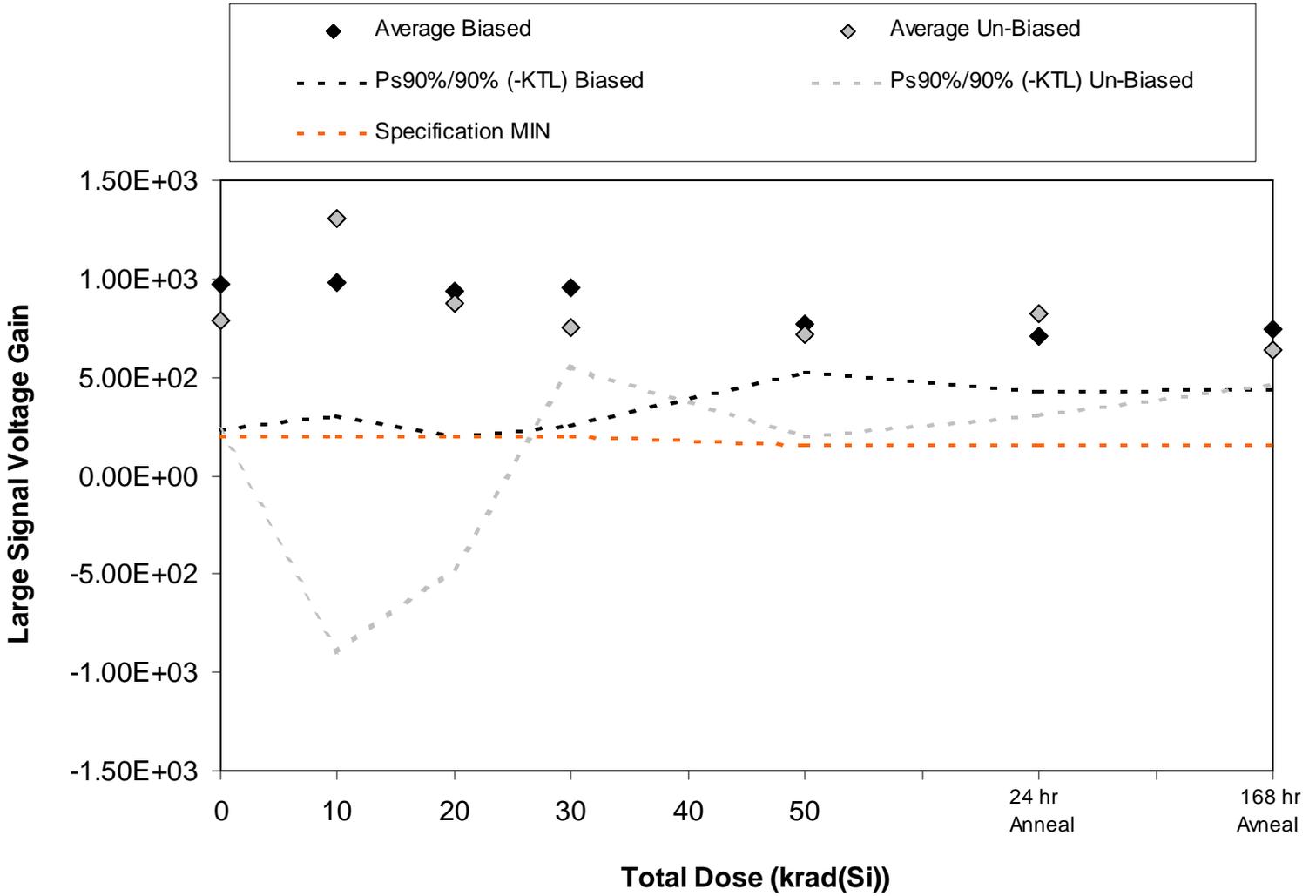


Figure 5.7. Plot of large signal voltage gain (AVOL) versus total dose. The data shows some degradation with total dose, however not sufficient for any of the units under test to fall below specification. With regards to the KTL values being “out of specification” Refer to the measurement resolution of Large Signal Voltage Gain Measurement in Appendix C, Table C.2, which shows that the measurement uncertainty of this parameter is significantly larger than the datasheet minimum of 200V/mV. Note that the standard deviation of the population actually improves with radiation due to the slight decrease in AVOL and a concomitant improvement in the measurement precision. 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.



Table 5.7. Raw data of large signal voltage gain (AVOL) versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail).

Large Signal Voltage Gain Device	Total Dose (krad(Si))					24H Anneal	168H Anneal
	0	10	20	30	50		
154	1.25E+03	1.05E+03	6.92E+02	7.97E+02	7.52E+02	8.22E+02	6.42E+02
155	1.15E+03	9.07E+02	6.42E+02	7.11E+02	6.92E+02	6.26E+02	8.77E+02
156	6.93E+02	1.37E+03	9.40E+02	1.32E+03	6.74E+02	6.74E+02	8.52E+02
157	1.10E+03	7.53E+02	1.22E+03	1.15E+03	8.64E+02	6.12E+02	6.99E+02
158	6.76E+02	8.22E+02	1.20E+03	8.22E+02	8.49E+02	8.22E+02	6.50E+02
159	6.35E+02	1.33E+03	5.45E+02	7.05E+02	1.02E+03	1.01E+03	6.76E+02
160	1.15E+03	1.22E+03	6.26E+02	6.82E+02	7.42E+02	7.23E+02	5.95E+02
161	7.42E+02	5.91E+02	1.08E+03	7.99E+02	6.87E+02	1.05E+03	6.50E+02
174	7.55E+02	7.57E+02	4.73E+02	7.08E+02	5.26E+02	7.13E+02	7.05E+02
163	6.75E+02	2.63E+03	1.64E+03	8.49E+02	6.12E+02	6.26E+02	5.48E+02
162	1.55E+03	1.12E+03	9.64E+02	1.06E+03	7.49E+02	1.35E+03	9.64E+02
Biased Statistics							
Average Biased	9.73E+02	9.82E+02	9.37E+02	9.59E+02	7.66E+02	7.11E+02	7.44E+02
Std Dev Biased	2.70E+02	2.46E+02	2.70E+02	2.59E+02	8.73E+01	1.04E+02	1.13E+02
Ps90%/90% (+KTL) Biased	1.71E+03	1.66E+03	1.68E+03	1.67E+03	1.01E+03	9.95E+02	1.05E+03
Ps90%/90% (-KTL) Biased	2.34E+02	3.07E+02	1.97E+02	2.47E+02	5.27E+02	4.27E+02	4.35E+02
Un-Biased Statistics							
Average Un-Biased	7.91E+02	1.30E+03	8.73E+02	7.48E+02	7.18E+02	8.24E+02	6.35E+02
Std Dev Un-Biased	2.06E+02	8.03E+02	4.91E+02	7.16E+01	1.89E+02	1.91E+02	6.32E+01
Ps90%/90% (+KTL) Un-Biased	1.36E+03	3.51E+03	2.22E+03	9.45E+02	1.24E+03	1.35E+03	8.08E+02
Ps90%/90% (-KTL) Un-Biased	2.27E+02	-8.96E+02	-4.74E+02	5.52E+02	2.00E+02	2.99E+02	4.61E+02
Specification MIN	2.00E+02	2.00E+02	2.00E+02	2.00E+02	1.50E+02	1.50E+02	1.50E+02
Status	PASS	FAIL	FAIL	PASS	PASS	PASS	PASS

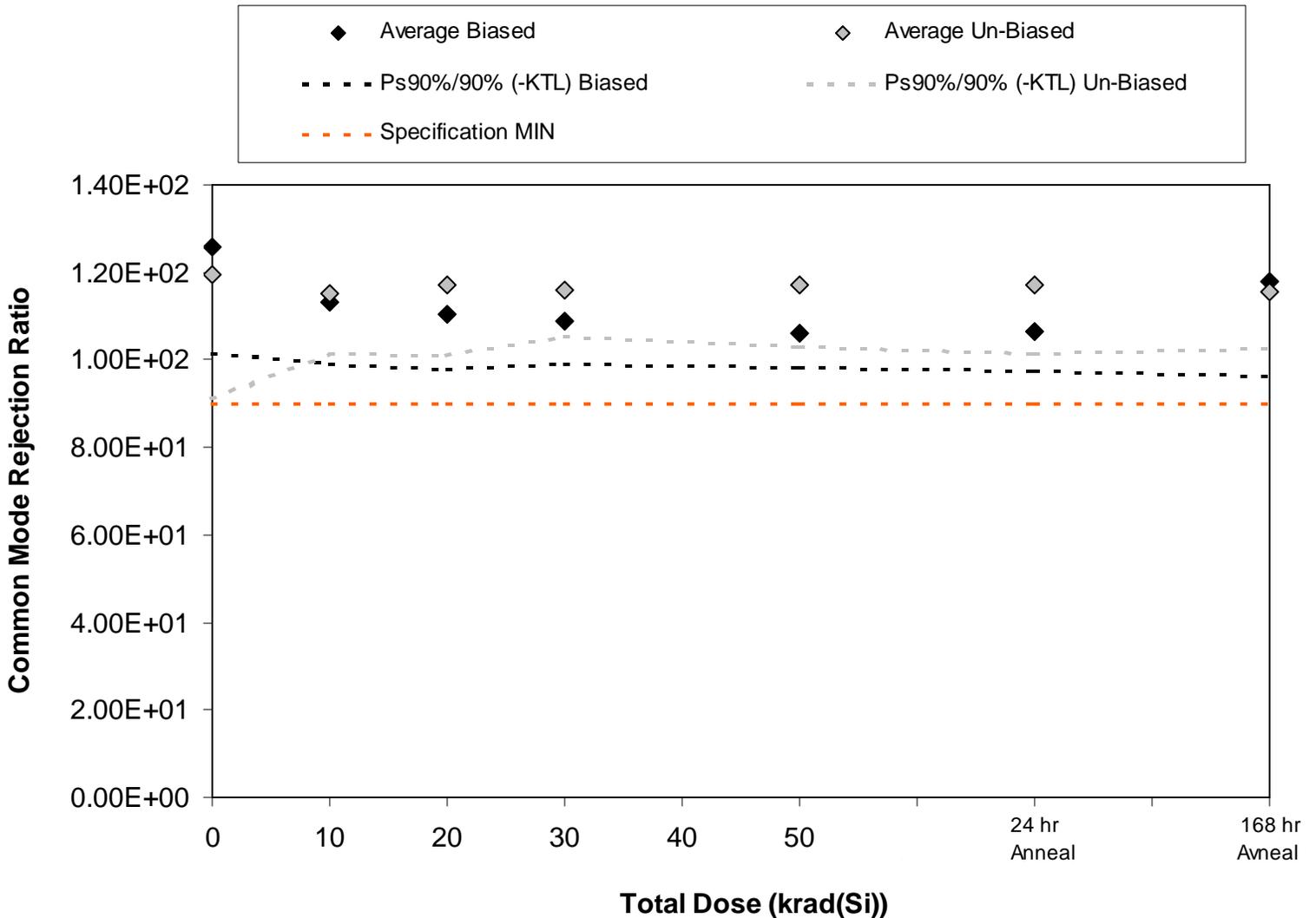


Figure 5.8. Plot of common mode rejection ratio (CMRR) versus total dose. The data shows some degradation with total dose, however not sufficient for any of the units under test to fall below specification. The solid diamonds are the average of the measured data points for the sample irradiated under 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.



Table 5.8. Raw data for the common mode rejection ratio (CMRR) versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail).

Common Mode Rejection Ratio	Total Dose (krad(Si))					24H	168H
	Device	0	10	20	30	50	Anneal
154	1.19E+02	1.10E+02	1.08E+02	1.06E+02	1.05E+02	1.05E+02	1.14E+02
155	1.22E+02	1.12E+02	1.09E+02	1.08E+02	1.07E+02	1.06E+02	1.14E+02
156	1.39E+02	1.15E+02	1.13E+02	1.12E+02	1.08E+02	1.08E+02	1.20E+02
157	1.31E+02	1.21E+02	1.18E+02	1.13E+02	1.09E+02	1.11E+02	1.31E+02
158	1.18E+02	1.08E+02	1.06E+02	1.05E+02	1.02E+02	1.02E+02	1.12E+02
159	1.12E+02	1.09E+02	1.11E+02	1.11E+02	1.13E+02	1.12E+02	1.10E+02
160	1.13E+02	1.11E+02	1.12E+02	1.13E+02	1.12E+02	1.13E+02	1.12E+02
161	1.15E+02	1.16E+02	1.18E+02	1.17E+02	1.15E+02	1.15E+02	1.16E+02
174	1.37E+02	1.21E+02	1.25E+02	1.21E+02	1.22E+02	1.24E+02	1.22E+02
163	1.21E+02	1.19E+02	1.20E+02	1.18E+02	1.23E+02	1.22E+02	1.18E+02
162	1.51E+02	1.28E+02	1.25E+02	1.19E+02	1.19E+02	1.29E+02	1.28E+02
Biased Statistics							
Average Biased	1.26E+02	1.13E+02	1.11E+02	1.09E+02	1.06E+02	1.07E+02	1.18E+02
Std Dev Biased	8.96E+00	5.17E+00	4.66E+00	3.49E+00	2.85E+00	3.43E+00	8.03E+00
Ps90%/90% (+KTL) Biased	1.50E+02	1.27E+02	1.23E+02	1.18E+02	1.14E+02	1.16E+02	1.40E+02
Ps90%/90% (-KTL) Biased	1.01E+02	9.89E+01	9.78E+01	9.91E+01	9.82E+01	9.72E+01	9.60E+01
Un-Biased Statistics							
Average Un-Biased	1.19E+02	1.15E+02	1.17E+02	1.16E+02	1.17E+02	1.17E+02	1.15E+02
Std Dev Un-Biased	1.03E+01	5.02E+00	5.91E+00	3.93E+00	5.14E+00	5.67E+00	4.72E+00
Ps90%/90% (+KTL) Un-Biased	1.48E+02	1.29E+02	1.33E+02	1.27E+02	1.31E+02	1.33E+02	1.28E+02
Ps90%/90% (-KTL) Un-Biased	9.11E+01	1.01E+02	1.01E+02	1.05E+02	1.03E+02	1.01E+02	1.03E+02
Specification MIN	9.00E+01	9.00E+01	9.00E+01	9.00E+01	9.00E+01	9.00E+01	9.00E+01
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

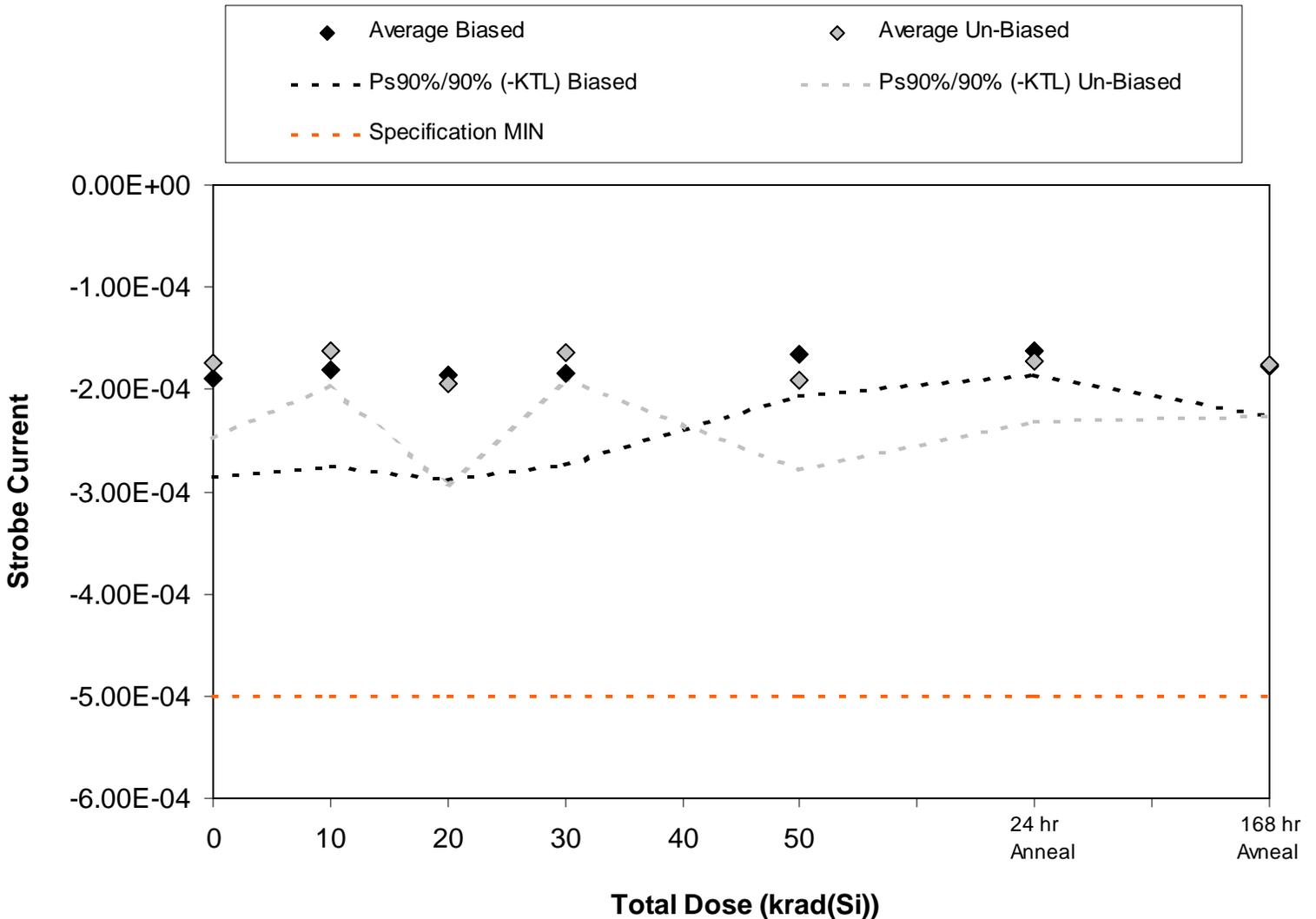


Figure 5.9. Plot of strobe current versus total dose. The data shows no significant degradation with dose. The solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the units 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.



Table 5.9. Raw data for strobe current versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail).

Strobe Current Device	Total Dose (krad(Si))					24H Anneal	168H Anneal
	0	10	20	30	50		
154	-1.56E-04	-1.62E-04	-1.65E-04	-1.56E-04	-1.56E-04	-1.56E-04	-1.77E-04
155	-1.56E-04	-2.35E-04	-2.18E-04	-1.81E-04	-1.56E-04	-1.56E-04	-1.75E-04
156	-1.90E-04	-1.56E-04	-1.56E-04	-1.56E-04	-1.74E-04	-1.56E-04	-1.77E-04
157	-2.13E-04	-1.56E-04	-1.56E-04	-1.96E-04	-1.88E-04	-1.73E-04	-2.06E-04
158	-2.35E-04	-1.99E-04	-2.35E-04	-2.35E-04	-1.56E-04	-1.70E-04	-1.56E-04
159	-1.75E-04	-1.56E-04	-1.64E-04	-1.56E-04	-1.91E-04	-1.56E-04	-1.65E-04
160	-1.56E-04	-1.56E-04	-2.35E-04	-1.58E-04	-1.56E-04	-1.56E-04	-1.74E-04
161	-2.20E-04	-1.56E-04	-2.35E-04	-1.56E-04	-2.35E-04	-1.97E-04	-2.05E-04
174	-1.56E-04	-1.56E-04	-1.76E-04	-1.76E-04	-2.11E-04	-1.56E-04	-1.57E-04
163	-1.63E-04	-1.84E-04	-1.64E-04	-1.71E-04	-1.66E-04	-1.96E-04	-1.78E-04
162	-1.56E-04	-1.91E-04	-1.56E-04	-1.81E-04	-1.92E-04	-1.56E-04	-2.12E-04
Biased Statistics							
Average Biased	-1.90E-04	-1.81E-04	-1.86E-04	-1.85E-04	-1.66E-04	-1.62E-04	-1.78E-04
Std Dev Biased	3.47E-05	3.45E-05	3.73E-05	3.26E-05	1.46E-05	8.52E-06	1.77E-05
Ps90%/90% (+KTL) Biased	-9.48E-05	-8.67E-05	-8.35E-05	-9.54E-05	-1.26E-04	-1.39E-04	-1.29E-04
Ps90%/90% (-KTL) Biased	-2.85E-04	-2.76E-04	-2.88E-04	-2.74E-04	-2.06E-04	-1.86E-04	-2.27E-04
Un-Biased Statistics							
Average Un-Biased	-1.74E-04	-1.62E-04	-1.95E-04	-1.63E-04	-1.92E-04	-1.72E-04	-1.76E-04
Std Dev Un-Biased	2.70E-05	1.23E-05	3.66E-05	9.37E-06	3.21E-05	2.19E-05	1.84E-05
Ps90%/90% (+KTL) Un-Biased	-1.00E-04	-1.28E-04	-9.43E-05	-1.38E-04	-1.04E-04	-1.12E-04	-1.25E-04
Ps90%/90% (-KTL) Un-Biased	-2.48E-04	-1.95E-04	-2.95E-04	-1.89E-04	-2.80E-04	-2.32E-04	-2.26E-04
Specification MIN	-5.00E-04	-5.00E-04	-5.00E-04	-5.00E-04	-5.00E-04	-5.00E-04	-5.00E-04
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

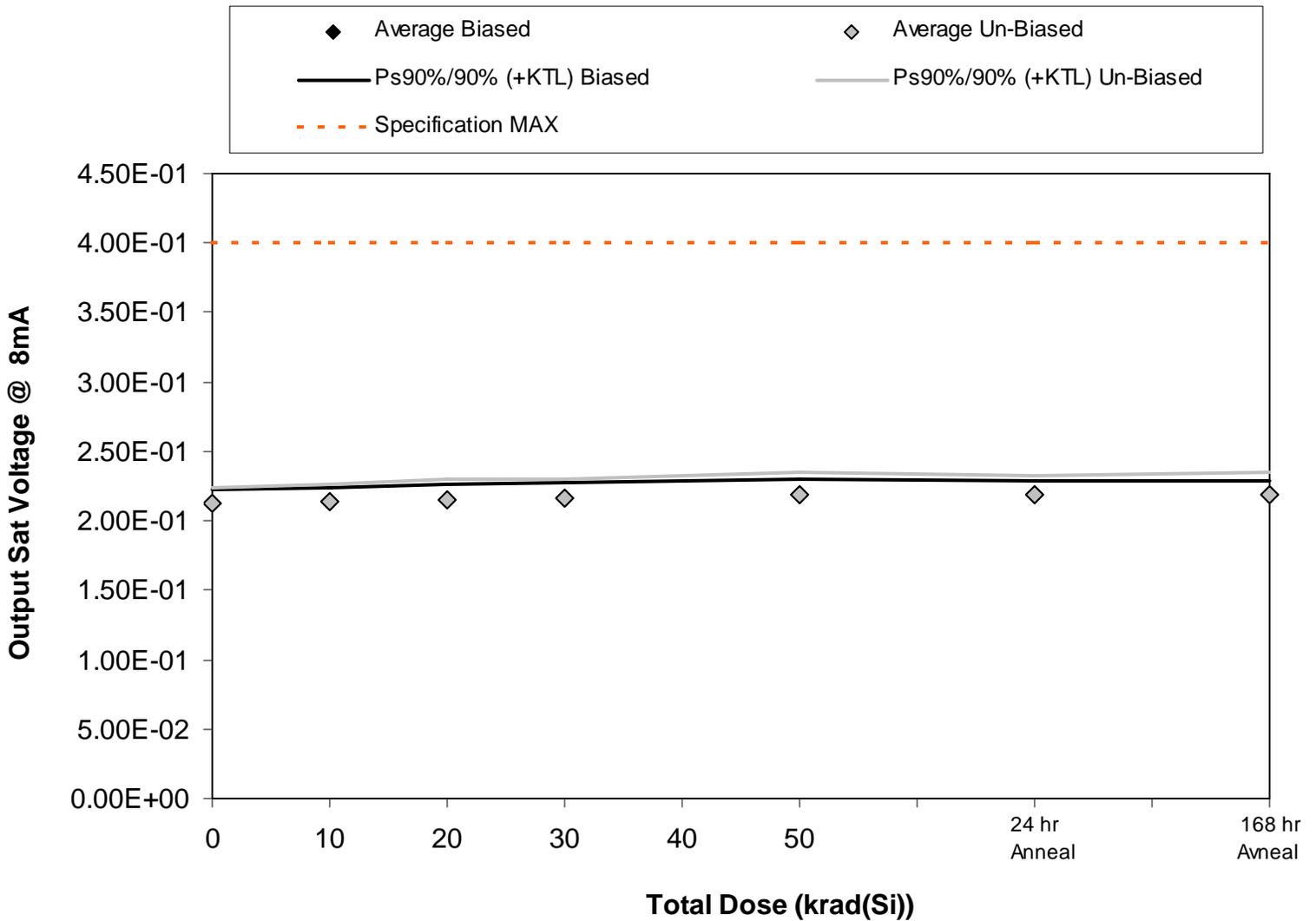


Figure 5.10. Plot of output saturation voltage (8mA load) versus total dose. The data show no significant degradation with dose. The solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured data 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.



Table 5.10. Raw data for output saturation voltage (8mA load) versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail).

Output Sat Voltage @ 8mA	Total Dose (krad(Si))					24H Anneal	168H Anneal
	0	10	20	30	50		
Device							
154	2.08E-01	2.09E-01	2.11E-01	2.11E-01	2.13E-01	2.14E-01	2.14E-01
155	2.18E-01	2.19E-01	2.22E-01	2.22E-01	2.24E-01	2.24E-01	2.24E-01
156	2.13E-01	2.13E-01	2.14E-01	2.16E-01	2.19E-01	2.18E-01	2.18E-01
157	2.13E-01	2.15E-01	2.15E-01	2.18E-01	2.20E-01	2.19E-01	2.19E-01
158	2.09E-01	2.10E-01	2.12E-01	2.15E-01	2.19E-01	2.19E-01	2.18E-01
159	2.14E-01	2.15E-01	2.17E-01	2.18E-01	2.20E-01	2.20E-01	2.21E-01
160	2.16E-01	2.18E-01	2.21E-01	2.21E-01	2.25E-01	2.24E-01	2.25E-01
161	2.13E-01	2.16E-01	2.17E-01	2.19E-01	2.21E-01	2.20E-01	2.19E-01
174	2.12E-01	2.14E-01	2.14E-01	2.15E-01	2.16E-01	2.17E-01	2.17E-01
163	2.05E-01	2.06E-01	2.06E-01	2.08E-01	2.09E-01	2.10E-01	2.09E-01
162	2.06E-01	2.07E-01	2.06E-01	2.07E-01	2.06E-01	2.06E-01	2.06E-01
Biased Statistics							
Average Biased	2.12E-01	2.13E-01	2.15E-01	2.16E-01	2.19E-01	2.19E-01	2.19E-01
Std Dev Biased	3.96E-03	4.02E-03	4.32E-03	4.04E-03	3.94E-03	3.56E-03	3.58E-03
Ps90%/90% (+KTL) Biased	2.23E-01	2.24E-01	2.27E-01	2.27E-01	2.30E-01	2.29E-01	2.28E-01
Ps90%/90% (-KTL) Biased	2.01E-01	2.02E-01	2.03E-01	2.05E-01	2.08E-01	2.09E-01	2.09E-01
Un-Biased Statistics							
Average Un-Biased	2.12E-01	2.14E-01	2.15E-01	2.16E-01	2.18E-01	2.18E-01	2.18E-01
Std Dev Un-Biased	4.18E-03	4.60E-03	5.61E-03	5.07E-03	6.06E-03	5.22E-03	5.93E-03
Ps90%/90% (+KTL) Un-Biased	2.23E-01	2.26E-01	2.30E-01	2.30E-01	2.35E-01	2.33E-01	2.34E-01
Ps90%/90% (-KTL) Un-Biased	2.01E-01	2.01E-01	2.00E-01	2.02E-01	2.02E-01	2.04E-01	2.02E-01
Specification MAX	4.00E-01	4.00E-01	4.00E-01	4.00E-01	4.00E-01	4.00E-01	4.00E-01
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

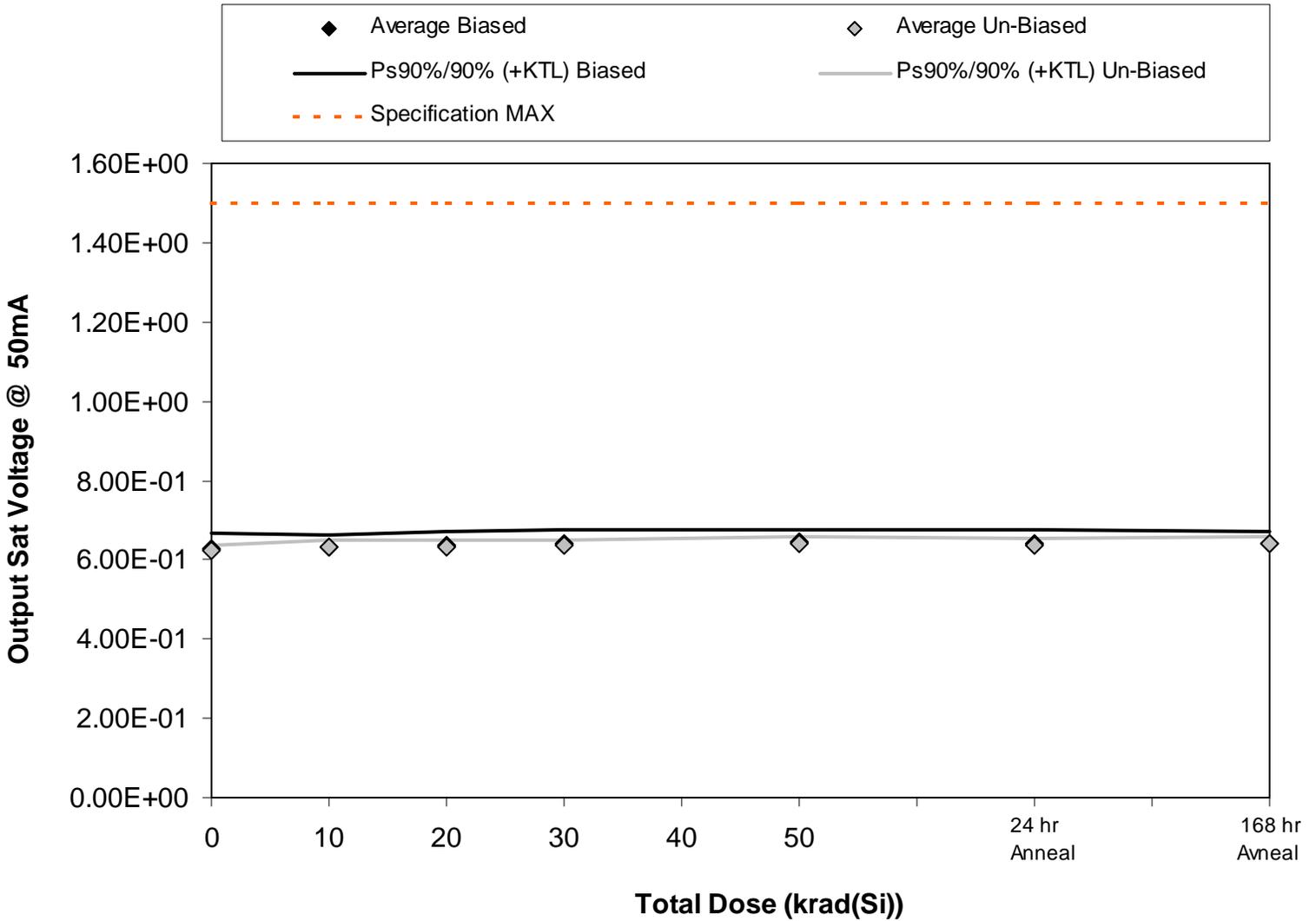


Figure 5.11. Plot of output saturation voltage (50mA load) versus total dose. The data show no significant degradation with dose. The solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured data 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.



Table 5.11. Raw data for output saturation voltage (50mA load) versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail).

Output Sat Voltage @ 50mA	Total Dose (krad(Si))					24H Anneal	168H Anneal
	0	10	20	30	50		
Device							
154	6.24E-01	6.28E-01	6.29E-01	6.34E-01	6.36E-01	6.35E-01	6.40E-01
155	6.49E-01	6.51E-01	6.58E-01	6.61E-01	6.63E-01	6.63E-01	6.61E-01
156	6.30E-01	6.32E-01	6.36E-01	6.44E-01	6.42E-01	6.42E-01	6.40E-01
157	6.23E-01	6.33E-01	6.32E-01	6.37E-01	6.38E-01	6.40E-01	6.38E-01
158	6.12E-01	6.20E-01	6.25E-01	6.27E-01	6.37E-01	6.35E-01	6.34E-01
159	6.22E-01	6.30E-01	6.31E-01	6.36E-01	6.37E-01	6.36E-01	6.40E-01
160	6.24E-01	6.34E-01	6.33E-01	6.40E-01	6.44E-01	6.44E-01	6.47E-01
161	6.30E-01	6.39E-01	6.40E-01	6.41E-01	6.46E-01	6.43E-01	6.42E-01
174	6.29E-01	6.37E-01	6.37E-01	6.39E-01	6.41E-01	6.36E-01	6.39E-01
163	6.18E-01	6.24E-01	6.26E-01	6.30E-01	6.31E-01	6.29E-01	6.27E-01
162	6.21E-01	6.26E-01	6.22E-01	6.28E-01	6.28E-01	6.24E-01	6.28E-01
Biased Statistics							
Average Biased	6.28E-01	6.33E-01	6.36E-01	6.41E-01	6.43E-01	6.43E-01	6.43E-01
Std Dev Biased	1.36E-02	1.14E-02	1.29E-02	1.29E-02	1.13E-02	1.16E-02	1.06E-02
Ps90%/90% (+KTL) Biased	6.65E-01	6.64E-01	6.71E-01	6.76E-01	6.74E-01	6.75E-01	6.72E-01
Ps90%/90% (-KTL) Biased	5.90E-01	6.02E-01	6.01E-01	6.05E-01	6.12E-01	6.11E-01	6.14E-01
Un-Biased Statistics							
Average Un-Biased	6.25E-01	6.33E-01	6.33E-01	6.37E-01	6.40E-01	6.38E-01	6.39E-01
Std Dev Un-Biased	4.98E-03	5.97E-03	5.41E-03	4.44E-03	5.97E-03	6.11E-03	7.38E-03
Ps90%/90% (+KTL) Un-Biased	6.38E-01	6.49E-01	6.48E-01	6.49E-01	6.56E-01	6.54E-01	6.59E-01
Ps90%/90% (-KTL) Un-Biased	6.11E-01	6.16E-01	6.19E-01	6.25E-01	6.23E-01	6.21E-01	6.19E-01
Specification MAX	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS

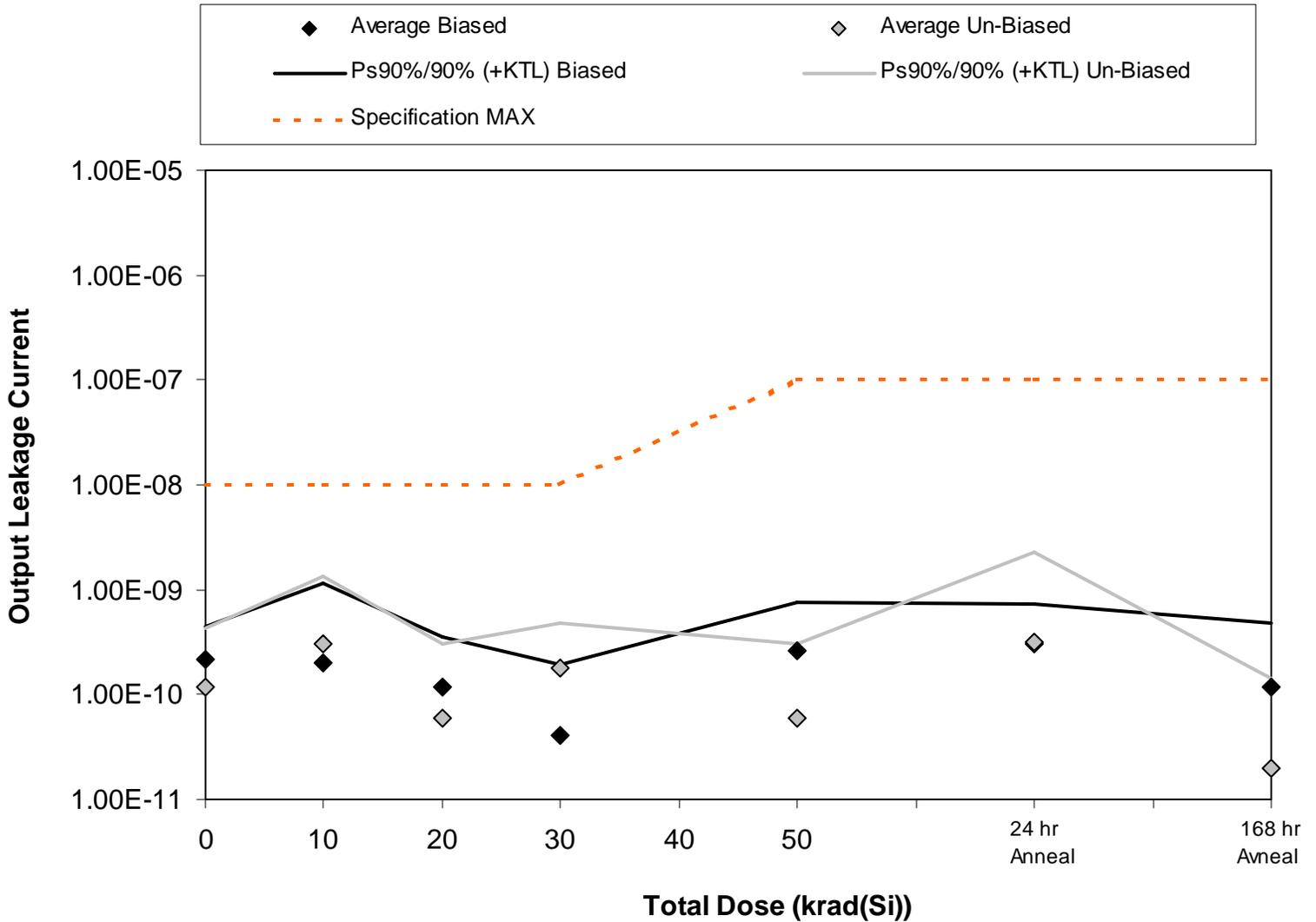


Figure 5.12. Plot of output leakage current versus total dose. The data show no significant degradation with dose. The solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the 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.



Table 5.12. Raw data for output leakage current versus total dose, including the statistical analysis, the specification and the status of the testing (pass/fail).

Output Leakage Current	Total Dose (krad(Si))					24H	168H
	0	10	20	30	50	Anneal	Anneal
Device							
154	3.00E-10	2.00E-10	2.00E-10	1.00E-10	4.00E-10	4.00E-10	3.00E-10
155	3.00E-10	8.00E-10	1.00E-10	0.00E+00	1.00E-10	1.00E-10	1.00E-10
156	2.00E-10	0.00E+00	2.00E-10	1.00E-10	2.00E-10	3.00E-10	0.00E+00
157	2.00E-10	0.00E+00	0.00E+00	0.00E+00	1.00E-10	2.00E-10	0.00E+00
158	1.00E-10	0.00E+00	1.00E-10	0.00E+00	5.00E-10	5.00E-10	2.00E-10
159	0.00E+00	6.00E-10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
160	2.00E-10	8.00E-10	0.00E+00	2.00E-10	0.00E+00	0.00E+00	0.00E+00
161	2.00E-10	1.00E-10	1.00E-10	2.00E-10	1.00E-10	0.00E+00	0.00E+00
174	0.00E+00	0.00E+00	0.00E+00	2.00E-10	0.00E+00	0.00E+00	0.00E+00
163	2.00E-10	0.00E+00	2.00E-10	3.00E-10	2.00E-10	1.60E-09	1.00E-10
162	2.00E-10	2.00E-10	1.00E-10	2.00E-10	2.00E-10	2.00E-10	0.00E+00
Biased Statistics							
Average Biased	2.20E-10	2.00E-10	1.20E-10	4.00E-11	2.60E-10	3.00E-10	1.20E-10
Std Dev Biased	8.37E-11	3.46E-10	8.37E-11	5.48E-11	1.82E-10	1.58E-10	1.30E-10
Ps90%/90% (+KTL) Biased	4.49E-10	1.15E-09	3.49E-10	1.90E-10	7.58E-10	7.34E-10	4.78E-10
Ps90%/90% (-KTL) Biased	-9.41E-12	-7.50E-10	-1.09E-10	-1.10E-10	-2.38E-10	-1.34E-10	-2.38E-10
Un-Biased Statistics							
Average Un-Biased	1.20E-10	3.00E-10	6.00E-11	1.80E-10	6.00E-11	3.20E-10	2.00E-11
Std Dev Un-Biased	1.10E-10	3.74E-10	8.94E-11	1.10E-10	8.94E-11	7.16E-10	4.47E-11
Ps90%/90% (+KTL) Un-Biased	4.20E-10	1.33E-09	3.05E-10	4.80E-10	3.05E-10	2.28E-09	1.43E-10
Ps90%/90% (-KTL) Un-Biased	-1.80E-10	-7.26E-10	-1.85E-10	-1.20E-10	-1.85E-10	-1.64E-09	-1.03E-10
Specification MAX	1.00E-08	1.00E-08	1.00E-08	1.00E-08	1.00E-07	1.00E-07	1.00E-07
Status	PASS	PASS	PASS	PASS	PASS	PASS	PASS



6.0. Summary / Conclusions

The low 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. For the low dose rate ELDRS testing described in this report, the devices were placed approximately 2-meters from the Co-60 rods to achieve the required 10mrad(Si)/s dose rate. Samples of the RH1011 voltage comparator 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 and 168hr 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 99/90 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 the ten-piece sample must pass the specification value when the KTL limits are applied. If these conditions were not both satisfied following the radiation exposure, then the lot would be logged as an RLAT failure.

Based on these criteria, the RH1011 voltage comparator discussed in this report passed the ELDRS test to the highest level tested of 50krad(Si). The following minor exceptions should be noted: AVOL was "out of specification" post-irradiation (10 and 20krad(Si) read points) and after application of the KTL statistics due to measurement precision limitations. However, the KTL statistics actually improved for AVOL with increasing radiation dose such that this parameter was within specification at the highest total dose of 50krad(Si). Similarly, the average values of the input offset voltage with the KTL statistics applied are outside of the specification due to the large standard deviation of the sample population relative to the pre-irradiation V_{OS} limit of 1.5mV. If any of these exceptions are a concern, we believe this lot could be qualified to the same statistical limits without any exceptions using a lot-tolerance-percent-defective (LTPD) approach.



Appendix A: TID Bias Connections

Biased Samples:

Pin	Function	Bias
1	GROUND	GND
2	+INPUT	5.1k Ω to +12V
3	-INPUT	GND
4	V-	12 Ω to -12V
5	BALANCE	N/C
6	BALANCE/STROBE	N/C
7	OUTPUT	5.1k Ω to +12V
8	V+	12 Ω to +12V

Unbiased Samples:

Pin	Function	Bias
1	GROUND	GND
2	+INPUT	GND
3	-INPUT	GND
4	V-	GND
5	BALANCE	GND
6	BALANCE/STROBE	GND
7	OUTPUT	GND
8	V+	GND

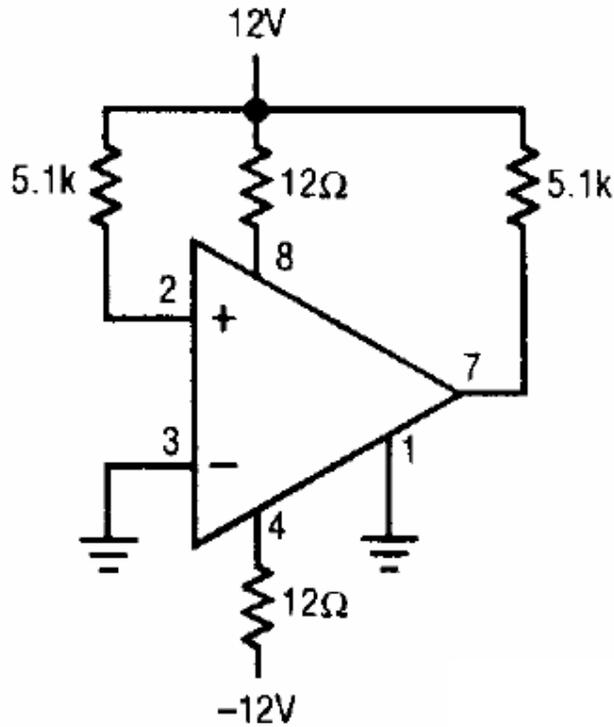
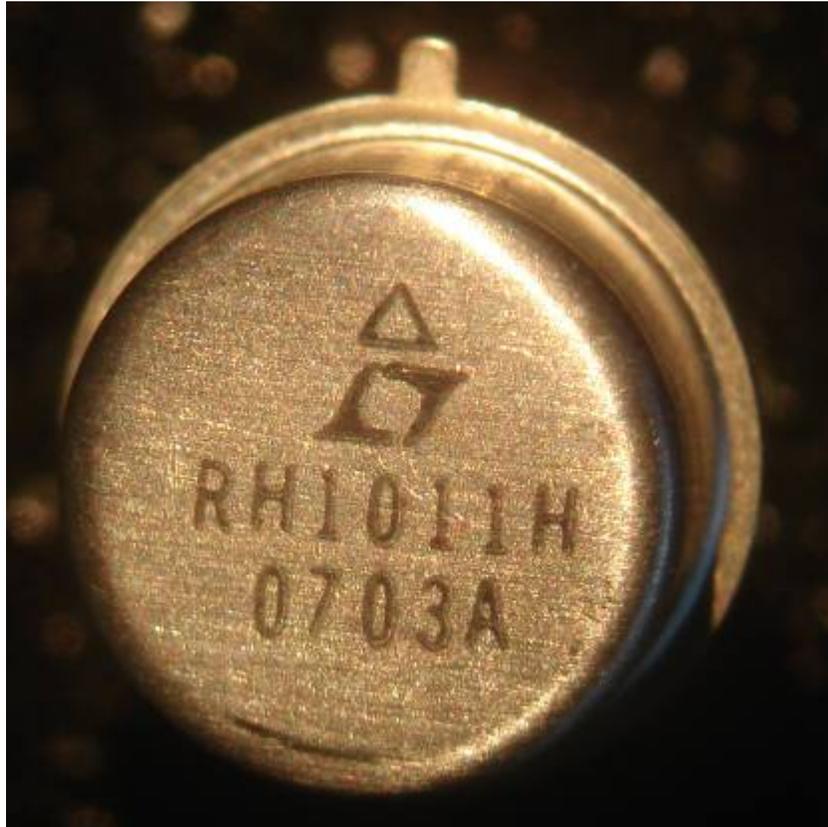


Figure A.1. Irradiation bias drawing for the units to be irradiated under electrical bias. This figure was extracted from LINEAR TECHNOLOGY CORPORATION, Drawing Number: 05-08-5012 REV. L "MICROCIRCUIT, LINEAR, MFG RH1011, VOLTAGE COMPARATOR".



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





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 tests are conducted using the LTS-2101 Linear Family Board, LTS-0608 Comparator Socket Assembly and DUT board. 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). Not all measured parameters are well suited to this approach due to inherent large variations. One such parameter is pre-irradiation Open Loop Gain, where the device exhibits extreme sensitivity to input conditions, resulting in a very large standard deviation. If necessary, larger samples sizes could be used to qualify these parameters using an "attributes" approach.



Table C.1. Measured parameters and test conditions for the RH1011H.

TEST NUMBER	TEST DESCRIPTION	TEST CONDITIONS
1	Positive Supply Current	$V_{+}=15V$, $V_{-}=-15V$ and $V_{GND}=0$
2	Negative Supply Current	$V_{+}=15V$, $V_{-}=-15V$ and $V_{GND}=0$
3	Input Offset Voltage	$V_{+}=15V$, $V_{-}=-15V$, Output is Sinking 1.5mA with $V_{OUT}=0V$
4	Input Offset Current	$V_{+}=15V$, $V_{-}=-15V$, Output is Sinking 1.5mA with $V_{OUT}=0V$
5	+ Input Bias Current	$V_{+}=15V$, $V_{-}=-15V$, Output is Sinking 1.5mA with $V_{OUT}=0V$
6	- Input Bias Current	$V_{+}=15V$, $V_{-}=-15V$, Output is Sinking 1.5mA with $V_{OUT}=0V$
7	Large Signal Voltage Gain	$V_{+}=15V$, $V_{-}=-15V$, $R=1k\Omega$ to +15V, $-10V \leq V_{OUT} \leq +14.5V$
8	Common Mode Rejection Ratio	$V_{+}=15V$, $V_{-}=-15V$, Common Mode Swing of $\pm 10V$
9	Strobe Current	Minimum to ensure output transistor turned off.
10	Output Sat Voltage @ 8mA	$V_{IN}=-5mV$ and $I_{SINK}=8mA$
11	Output Sat Voltage @ 50mA	$V_{IN}=0$ and $I_{SINK}=50mA$
12	Output Leakage Current	$V_{+}=15V$, $V_{-}=-15V$, $V_{IN}=5mV$, $V_{GND}=-15V$, $V_{OUT}=20V$



Table C.2. Measured parameters, pre-irradiation specifications and measurement resolution for the RH1011H.

Measured Parameter	Pre-Irradiation Specification	Measurement Resolution/Precision
Positive Supply Current	4.0mA	$\pm 7.34E-05A$
Negative Supply Current	-2.5mA	$\pm 4.69E-05A$
Input Offset Voltage	$\pm 1.5mV$	$\pm 1.99E-05V$
Input Offset Current	$\pm 4.0nA$	$\pm 2.44E-10A$
+ Input Bias Current	-50nA	$\pm 6.30E-10A$
- Input Bias Current	-50nA	$\pm 2.05E-10A$
Large Signal Voltage Gain	200V/mV	$\pm 5.17E+02V/mV$
Common Mode Rejection Ratio	90dB	$\pm 5.94E+00dB$
Strobe Current	-500 μA	$\pm 6.84E-05A$
Output Sat Voltage @ 8mA	0.4V	$\pm 1.74E-03V$
Output Sat Voltage @ 50mA	1.5V	$\pm 8.40E-03V$
Output Leakage Current	10nA	$\pm 1.74E-10A$