RLAT Report
09-128 090515 R1.1

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

Radiation Lot Acceptance Testing (RLAT) of the RH101AW Operational Amplifier for Linear Technology

Customer: Linear Technology, PO# 52346L

RAD Job Number: 09-128

Part Type Tested: Linear Technology RH101AW Operational Amplifier

Traceability Information: Fab lot# WP1200.2, Wafer# 10, Assembly Lot #509533.1. Information obtained from Linear Technology PO#52346L. Date code marking on the package is 0851A; see Appendix A for a photograph of the device for part markings.

Quantity of Units: 11 units total, 5 units for biased irradiation, 5 units for unbiased irradiation and 1 control unit. Serial numbers 1, 24, 25, 41 and 42 were biased during irradiation. Serial numbers 62, 102, 105, 122 and 125 were unbiased during irradiation (all pins tied to ground). Serial numbers 142 and 152 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 Devices prior to receipt by RAD.

TID Dose Rate and Test Increments: 62rad(Si)/s with readings at pre-irradiation, 20, 50, 100, and 200krad(Si).

TID Overtest and Post-Irradiation Anneal: No overtest or anneal.

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

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

Test Hardware: LTS2020 Tester, Entity ID: TS03, Calibration Date 05/03/09 Calibration Due 05/03/10.

Facility and Radiation Source: Radiation Assured Devices Longmire Laboratories, Colorado Springs, CO using the JLSA 81-24 high 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

RLAT Result: Units Passed to 200krad(Si) with all parameters remaining within specification and with no significant degradation to most of the measured parameters

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 and interface regions. In discrete devices the bulk of the damage is frequently manifested as a reduction in the gain and/or breakdown voltage of the device. The damage will usually anneal with time following the end of the radiation exposure. Due to this annealing, and to ensure a worst-case test condition MIL-STD-883 TM1019.7 calls out a dose rate of 50 to 300rad(Si)/s as Condition A and further specifies that the time from the end of an incremental radiation exposure and electrical testing shall be 1-hour or less and the total time from the end of one incremental irradiation to the beginning of the next incremental radiation step should be 2-hours or less. The work described in this report was performed to meet MIL-STD-883 TM1019.7 Condition A.

2.0. Radiation Test Apparatus

The 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 Co-60 rods are held in the base of the irradiator heavily shielded by lead, during the radiation 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 <1rad(Si)/s to a maximum of approximately 120rad(Si)/s, determined by the distance from the source. For high-dose rate experiments the bias boards are placed in a radial fashion equidistant from the raised Co-60 rods with the distance adjusted to provide the required dose rate. 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 JLSA 81-24 Co-60 irradiator at RAD's Longmire Laboratory facility.

RAD is currently certified by the Defense Supply Center Columbus (DSCC) for Laboratory Suitability under MIL STD 750. Additional details regarding Radiation Assured Devices dosimetry for TM1019 Condition A testing are available in RAD's report to DSCC entitled: "Dose Rate Mapping of the J.L. Shepherd and Associates Model 81 Irradiator Installed by Radiation Assured Devices"

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

Figure 2.1. Radiation Assured Devices' high dose rate 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 120rad(Si)/s close to the rods down to 1rad(Si)/s at a distance of approximately 2-feet.

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

3.0. Radiation Test Conditions

The RH101 operational amplifiers described in this final report were irradiated using a split 15V supply and with all pins tied to ground, that is biased and unbiased. See the TID Bias Table in Appendix B for the full bias circuits. 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 200krad(Si) with incremental readings at 20, 50, 100 and 200krad(Si). Electrical testing occurred within one hour following the end of each irradiation segment. For intermediate irradiations, the parts 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 dose rate range of 50rad(Si)/s to 300rad(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 high dose rate lead-aluminum enclosure was determined based on TLD dosimetry measurements (see previous section). The final dose rate for this work was 62rad(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

During the radiation lot acceptance testing the pre- and post-irradiation electrical parameters measured were:

1. Supply Current (Positive Supply), I_{CC}
2. Supply Current (Negative Supply), I_{EE}
3. Input Offset Voltage, V_{OS}
4. Input Offset Current, I_{OS}
5. Input Bias Current, Non-Inverting Input, I_{B+}
6. Input Bias Current, Inverting Input, I_{B-}
7. Common Mode Rejection Ratio, CMRR
8. Power Supply Rejection Ratio, PSRR
9. Large Signal Voltage Gain, AVOL
10. Maximum Output Voltage Swing, PostiveV_{OUT+1}
11. Maximum Output Voltage Swing, Negative V_{OUT-1}
12. Maximum Output Voltage Swing, PostiveV_{OUT+2}
13. Maximum Output Voltage Swing, Negative V_{OUT-2}

The parametric data was obtained as read and record and all the raw data plus an attributes summary are contained in a separate Excel file. The attributes data contains the average, standard deviation and the average with the KTL values applied. The KTL value used is 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 must be met for a device to pass the RLAT: following the radiation exposure each of the 5 pieces shall 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 either of these conditions is not satisfied following the radiation exposure, then the lot could be logged as a failure.

5.0. Total Ionizing Dose Test Results

The RH101 operational amplifiers (with the traceability identified on the first page of this report) passed the RLAT to the maximum level tested of 200krad(Si) with no significant degradation to most of the measured parameters. Open loop gain exhibited some degradation with radiation, however it was not sufficient to cause the parameter to fall out of specification even after application of the KTL statistics. Figures 5.1 and 5.13 show plots of all the measured parameters versus total ionizing dose while Tables 5.1 – 5.13 show the corresponding raw data for each of these parameters.

In the data plots the solid diamonds are the average of the measured data points for the sample irradiated under electrical bias while the shaded diamonds are the average of the measured data points for the units

irradiated with all pins tied to ground. The black lines (solid or dashed) are the 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. The control units, as expected, show no significant changes throughout the test.

As seen clearly in these tables and figures, the pre- and post-irradiation data are well within the specification even after application of the KTL statistics. The control units, as expected, show no significant changes to any of the parameters. Therefore we can conclude that the electrical testing remained in control throughout the duration of the tests and the degradation observed was due to the radiation exposure.

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 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.

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

Average Biased
Average Un-Biased
Ps90%/90% (+KTL) Biased
Ps90%/90% (+KTL) Un-Biased
Specification MAX

Positive Power Supply Current (A)
3.50E-03
3.00E-03
2.50E-03
2.00E-03
1.50E-03
1.00E-03
5.00E-04
0.00E+00

0 20 40 60 80 100 120 140 160 180 200

Total Dose (krad(Si))

Figure 5.1. Plot of Positive Power Supply Current (A) versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values 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 Positive Power Supply Current (A) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Positive Power Supply Current (A)	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	1.51E-03	1.49E-03	1.47E-03	1.45E-03	1.43E-03
24	1.52E-03	1.49E-03	1.48E-03	1.46E-03	1.44E-03
25	1.53E-03	1.50E-03	1.49E-03	1.47E-03	1.45E-03
41	1.53E-03	1.51E-03	1.48E-03	1.47E-03	1.45E-03
42	1.53E-03	1.50E-03	1.49E-03	1.47E-03	1.44E-03
62	1.49E-03	1.47E-03	1.45E-03	1.41E-03	1.37E-03
102	1.53E-03	1.51E-03	1.48E-03	1.45E-03	1.40E-03
105	1.56E-03	1.53E-03	1.50E-03	1.48E-03	1.43E-03
122	1.50E-03	1.48E-03	1.45E-03	1.42E-03	1.37E-03
125	1.53E-03	1.51E-03	1.48E-03	1.45E-03	1.41E-03
142	1.54E-03	1.53E-03	1.53E-03	1.53E-03	1.53E-03
152	1.51E-03	1.52E-03	1.52E-03	1.52E-03	1.51E-03
Biased Statistics					
Average Biased	1.52E-03	1.50E-03	1.48E-03	1.46E-03	1.44E-03
Std Dev Biased	8.94E-06	8.37E-06	8.37E-06	8.94E-06	8.37E-06
Ps90%/90% (+KTL) Biased	1.55E-03	1.52E-03	1.50E-03	1.49E-03	1.46E-03
Ps90%/90% (-KTL) Biased	1.50E-03	1.48E-03	1.46E-03	1.44E-03	1.42E-03
Un-Biased Statistics					
Average Un-Biased	1.52E-03	1.50E-03	1.47E-03	1.44E-03	1.40E-03
Std Dev Un-Biased	2.77E-05	2.45E-05	2.17E-05	2.77E-05	2.61E-05
Ps90%/90% (+KTL) Un-Biased	1.60E-03	1.57E-03	1.53E-03	1.52E-03	1.47E-03
Ps90%/90% (-KTL) Un-Biased	1.45E-03	1.43E-03	1.41E-03	1.37E-03	1.32E-03
Specification MAX	3.00E-03	3.00E-03	3.00E-03	3.00E-03	3.00E-03
Status	PASS	PASS	PASS	PASS	PASS

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Specification MIN

Negative Power Supply Current (A)
0.00E+00
-5.00E-04
-1.00E-03
-1.50E-03
-2.00E-03
-2.50E-03
-3.00E-03
-3.50E-03
0 20 40 60 80 100 120 140 160 180 200
Total Dose (krad(Si))

Figure 5.2. Plot of Negative Power Supply Current (A) versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values 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 Negative Power Supply Current (A) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Negative Power Supply Current (A)	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	-1.51E-03	-1.50E-03	-1.47E-03	-1.46E-03	-1.44E-03
24	-1.52E-03	-1.50E-03	-1.48E-03	-1.47E-03	-1.44E-03
25	-1.53E-03	-1.51E-03	-1.49E-03	-1.47E-03	-1.45E-03
41	-1.54E-03	-1.51E-03	-1.48E-03	-1.47E-03	-1.45E-03
42	-1.53E-03	-1.50E-03	-1.49E-03	-1.48E-03	-1.45E-03
62	-1.50E-03	-1.47E-03	-1.45E-03	-1.42E-03	-1.36E-03
102	-1.53E-03	-1.51E-03	-1.48E-03	-1.46E-03	-1.40E-03
105	-1.56E-03	-1.53E-03	-1.51E-03	-1.48E-03	-1.44E-03
122	-1.51E-03	-1.49E-03	-1.46E-03	-1.42E-03	-1.38E-03
125	-1.54E-03	-1.52E-03	-1.48E-03	-1.46E-03	-1.41E-03
142	-1.54E-03	-1.54E-03	-1.54E-03	-1.54E-03	-1.53E-03
152	-1.52E-03	-1.52E-03	-1.52E-03	-1.52E-03	-1.52E-03
Biased Statistics					
Average Biased	-1.53E-03	-1.50E-03	-1.48E-03	-1.47E-03	-1.45E-03
Std Dev Biased	1.14E-05	5.48E-06	8.37E-06	7.07E-06	5.48E-06
Ps90%/90% (+KTL) Biased	-1.49E-03	-1.49E-03	-1.46E-03	-1.45E-03	-1.43E-03
Ps90%/90% (-KTL) Biased	-1.56E-03	-1.52E-03	-1.50E-03	-1.49E-03	-1.46E-03
Un-Biased Statistics					
Average Un-Biased	-1.53E-03	-1.50E-03	-1.48E-03	-1.45E-03	-1.40E-03
Std Dev Un-Biased	2.39E-05	2.41E-05	2.30E-05	2.68E-05	3.03E-05
Ps90%/90% (+KTL) Un-Biased	-1.46E-03	-1.44E-03	-1.41E-03	-1.37E-03	-1.31E-03
Ps90%/90% (-KTL) Un-Biased	-1.59E-03	-1.57E-03	-1.54E-03	-1.52E-03	-1.48E-03
Specification MIN	-3.00E-03	-3.00E-03	-3.00E-03	-3.00E-03	-3.00E-03
Status	PASS	PASS	PASS	PASS	PASS

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Ps90%/90% (+KTL) Biased
Ps90%/90% (+KTL) Un-Biased
Specification MIN
Specification MAX

Input Offset Voltage (V)
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
-1.00E-03
-2.00E-03
-3.00E-03
-4.00E-03

0 20 40 60 80 100 120 140 160 180 200
Total Dose (krad(Si))

Figure 5.3. Plot of Input Offset Voltage (V) versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values 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 Input Offset Voltage (V) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Input Offset Voltage (V)	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	0.00E+00	-4.00E-06	-1.00E-05	-1.40E-05	-1.30E-05
24	4.00E-06	-2.00E-06	0.00E+00	-5.00E-06	-1.20E-05
25	-1.40E-05	-4.30E-05	-4.60E-05	-4.70E-05	-5.20E-05
41	1.20E-04	1.17E-04	1.17E-04	1.15E-04	1.11E-04
42	1.43E-04	1.38E-04	1.36E-04	1.37E-04	1.33E-04
62	1.81E-04	1.71E-04	1.72E-04	1.63E-04	1.59E-04
102	2.03E-04	2.07E-04	2.00E-04	1.95E-04	1.87E-04
105	4.80E-05	3.50E-05	2.70E-05	1.70E-05	0.00E+00
122	1.42E-04	1.45E-04	1.45E-04	1.38E-04	1.26E-04
125	1.62E-04	1.67E-04	1.62E-04	1.51E-04	1.35E-04
142	5.10E-05	5.80E-05	5.60E-05	5.70E-05	5.70E-05
152	1.44E-04	1.50E-04	1.50E-04	1.49E-04	1.49E-04
Biased Statistics					
Average Biased	5.06E-05	4.12E-05	3.94E-05	3.72E-05	3.34E-05
Std Dev Biased	7.46E-05	8.08E-05	8.16E-05	8.29E-05	8.28E-05
Ps90%/90% (+KTL) Biased	2.55E-04	2.63E-04	2.63E-04	2.65E-04	2.61E-04
Ps90%/90% (-KTL) Biased	-1.54E-04	-1.80E-04	-1.84E-04	-1.90E-04	-1.94E-04
Un-Biased Statistics					
Average Un-Biased	1.47E-04	1.45E-04	1.41E-04	1.33E-04	1.21E-04
Std Dev Un-Biased	5.99E-05	6.54E-05	6.69E-05	6.81E-05	7.19E-05
Ps90%/90% (+KTL) Un-Biased	3.11E-04	3.24E-04	3.25E-04	3.20E-04	3.18E-04
Ps90%/90% (-KTL) Un-Biased	-1.70E-05	-3.43E-05	-4.22E-05	-5.39E-05	-7.57E-05
Specification MIN	-2.00E-03	-2.00E-03	-2.00E-03	-2.00E-03	-3.00E-03
Status	PASS	PASS	PASS	PASS	PASS
Specification MAX	2.00E-03	2.00E-03	2.00E-03	2.00E-03	3.00E-03
Status	PASS	PASS	PASS	PASS	PASS

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

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Ps90%/90% (+KTL) Biased
Ps90%/90% (+KTL) Un-Biased
Specification MIN
Specification MAX

Input Offset Current (A)
2.50E-08
2.00E-08
1.50E-08
1.00E-08
5.00E-09
0.00E+00
-5.00E-09
-1.00E-08
-1.50E-08
-2.00E-08
-2.50E-08

0 20 40 60 80 100 120 140 160 180 200
Total Dose (krad(Si))

Figure 5.4. Plot of Input Offset Current (A) versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values 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 Input Offset Current (A) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Input Offset Current (A)	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	3.73E-10	-2.65E-10	8.00E-12	1.40E-10	2.41E-10
24	6.26E-10	4.98E-10	6.98E-10	9.57E-10	1.15E-09
25	9.80E-11	-1.22E-10	-9.00E-11	-2.16E-10	-6.30E-11
41	1.57E-09	1.26E-09	1.56E-09	1.79E-09	1.97E-09
42	1.23E-09	1.14E-09	1.36E-09	1.68E-09	1.76E-09
62	1.38E-09	-1.80E-11	-4.50E-11	-8.50E-11	8.30E-11
102	4.85E-10	-5.65E-10	-3.74E-10	-4.88E-10	-2.12E-10
105	1.16E-09	1.90E-10	5.99E-10	9.52E-10	1.34E-09
122	1.32E-09	3.91E-10	5.42E-10	6.91E-10	1.01E-09
125	1.47E-09	6.63E-10	1.04E-09	1.28E-09	1.67E-09
142	1.43E-09	1.40E-09	1.38E-09	1.36E-09	1.37E-09
152	6.71E-10	6.35E-10	6.35E-10	6.35E-10	6.14E-10
Biased Statistics					
Average Biased	7.79E-10	5.02E-10	7.07E-10	8.71E-10	1.01E-09
Std Dev Biased	6.08E-10	6.99E-10	7.55E-10	8.99E-10	8.99E-10
Ps90%/90% (+KTL) Biased	2.45E-09	2.42E-09	2.78E-09	3.34E-09	3.48E-09
Ps90%/90% (-KTL) Biased	-8.88E-10	-1.42E-09	-1.36E-09	-1.59E-09	-1.46E-09
Un-Biased Statistics					
Average Un-Biased	1.16E-09	1.32E-10	3.52E-10	4.69E-10	7.79E-10
Std Dev Un-Biased	3.94E-10	4.64E-10	5.59E-10	7.35E-10	8.10E-10
Ps90%/90% (+KTL) Un-Biased	2.24E-09	1.40E-09	1.89E-09	2.48E-09	3.00E-09
Ps90%/90% (-KTL) Un-Biased	8.19E-11	-1.14E-09	-1.18E-09	-1.54E-09	-1.44E-09
Specification MIN	-1.00E-08	-1.00E-08	-1.00E-08	-1.00E-08	-2.00E-08
Status	PASS	PASS	PASS	PASS	PASS
Specification MAX	1.00E-08	1.00E-08	1.00E-08	1.00E-08	2.00E-08
Status	PASS	PASS	PASS	PASS	PASS

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

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Ps90%/90% (+KTL) Biased
Ps90%/90% (+KTL) Un-Biased
Specification MIN
Specification MAX

Positive Input Bias Current (A)

5.00E-07
4.00E-07
3.00E-07
2.00E-07
1.00E-07
0.00E+00
-1.00E-07
-2.00E-07
-3.00E-07
-4.00E-07
-5.00E-07

0 20 40 60 80 100 120 140 160 180 200

Total Dose (krad(Si))

Figure 5.5. Plot of Positive Input Bias Current (A) versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values 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 Positive Input Bias Current (A) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Positive Input Bias Current (A)	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	-4.69E-08	-4.85E-08	-5.09E-08	-5.41E-08	-5.87E-08
24	-4.69E-08	-4.85E-08	-5.07E-08	-5.40E-08	-5.90E-08
25	-4.60E-08	-4.83E-08	-5.05E-08	-5.39E-08	-5.80E-08
41	-4.83E-08	-4.98E-08	-5.20E-08	-5.54E-08	-6.09E-08
42	-4.86E-08	-4.99E-08	-5.23E-08	-5.57E-08	-6.08E-08
62	-3.66E-08	-4.22E-08	-4.56E-08	-5.12E-08	-6.00E-08
102	-3.81E-08	-4.28E-08	-4.63E-08	-5.13E-08	-5.98E-08
105	-5.19E-08	-5.76E-08	-6.22E-08	-6.88E-08	-8.00E-08
122	-4.35E-08	-4.81E-08	-5.20E-08	-5.85E-08	-6.77E-08
125	-4.88E-08	-5.37E-08	-5.79E-08	-6.39E-08	-7.37E-08
142	-4.73E-08	-4.75E-08	-4.74E-08	-4.75E-08	-4.75E-08
152	-4.96E-08	-4.95E-08	-4.95E-08	-4.95E-08	-4.96E-08
Biased Statistics					
Average Biased	-4.73E-08	-4.90E-08	-5.13E-08	-5.46E-08	-5.95E-08
Std Dev Biased	1.09E-09	7.92E-10	8.00E-10	8.65E-10	1.30E-09
Ps90%/90% (+KTL) Biased	-4.44E-08	-4.68E-08	-4.91E-08	-5.22E-08	-5.59E-08
Ps90%/90% (-KTL) Biased	-5.03E-08	-5.12E-08	-5.35E-08	-5.70E-08	-6.30E-08
Un-Biased Statistics					
Average Un-Biased	-4.38E-08	-4.89E-08	-5.28E-08	-5.87E-08	-6.82E-08
Std Dev Un-Biased	6.63E-09	6.75E-09	7.23E-09	7.75E-09	8.76E-09
Ps90%/90% (+KTL) Un-Biased	-2.56E-08	-3.03E-08	-3.30E-08	-3.75E-08	-4.42E-08
Ps90%/90% (-KTL) Un-Biased	-6.20E-08	-6.74E-08	-7.26E-08	-8.00E-08	-9.22E-08
Specification MIN	-7.50E-08	-7.50E-08	-1.00E-07	-2.00E-07	-4.00E-07
Status	PASS	PASS	PASS	PASS	PASS
Specification MAX	7.50E-08	7.50E-08	1.00E-07	2.00E-07	4.00E-07
Status	PASS	PASS	PASS	PASS	PASS

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

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Ps90%/90% (+KTL) Biased
Ps90%/90% (+KTL) Un-Biased
Specification MIN
Specification MAX

Negative Input Bias Current (A)
5.00E-07
4.00E-07
3.00E-07
2.00E-07
1.00E-07
0.00E+00
-1.00E-07
-2.00E-07
-3.00E-07
-4.00E-07
-5.00E-07

0 20 40 60 80 100 120 140 160 180 200
Total Dose (krad(Si))

Figure 5.6. Plot of Negative Input Bias Current (A) versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values 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 Negative Input Bias Current (A) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Negative Input Bias Current (A)	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	-4.73E-08	-4.83E-08	-5.08E-08	-5.42E-08	-5.89E-08
24	-4.75E-08	-4.90E-08	-5.14E-08	-5.49E-08	-6.01E-08
25	-4.61E-08	-4.82E-08	-5.04E-08	-5.37E-08	-5.79E-08
41	-4.99E-08	-5.11E-08	-5.35E-08	-5.72E-08	-6.29E-08
42	-4.98E-08	-5.10E-08	-5.37E-08	-5.73E-08	-6.26E-08
62	-3.80E-08	-4.21E-08	-4.55E-08	-5.12E-08	-6.01E-08
102	-3.86E-08	-4.22E-08	-4.59E-08	-5.07E-08	-5.96E-08
105	-5.31E-08	-5.77E-08	-6.28E-08	-6.96E-08	-8.12E-08
122	-4.48E-08	-4.85E-08	-5.25E-08	-5.91E-08	-6.87E-08
125	-5.03E-08	-5.43E-08	-5.89E-08	-6.52E-08	-7.53E-08
142	-4.87E-08	-4.89E-08	-4.88E-08	-4.89E-08	-4.88E-08
152	-5.02E-08	-5.01E-08	-5.02E-08	-5.01E-08	-5.02E-08
Biased Statistics					
Average Biased	-4.81E-08	-4.95E-08	-5.20E-08	-5.54E-08	-6.05E-08
Std Dev Biased	1.66E-09	1.43E-09	1.52E-09	1.70E-09	2.20E-09
Ps90%/90% (+KTL) Biased	-4.35E-08	-4.56E-08	-4.78E-08	-5.08E-08	-5.44E-08
Ps90%/90% (-KTL) Biased	-5.27E-08	-5.34E-08	-5.61E-08	-6.01E-08	-6.65E-08
Un-Biased Statistics					
Average Un-Biased	-4.50E-08	-4.90E-08	-5.31E-08	-5.92E-08	-6.90E-08
Std Dev Un-Biased	6.78E-09	7.04E-09	7.70E-09	8.39E-09	9.42E-09
Ps90%/90% (+KTL) Un-Biased	-2.64E-08	-2.97E-08	-3.20E-08	-3.62E-08	-4.32E-08
Ps90%/90% (-KTL) Un-Biased	-6.35E-08	-6.83E-08	-7.42E-08	-8.22E-08	-9.48E-08
Specification MIN	-7.50E-08	-7.50E-08	-1.00E-07	-2.00E-07	-4.00E-07
Status	PASS	PASS	PASS	PASS	PASS
Specification MAX	7.50E-08	7.50E-08	1.00E-07	2.00E-07	4.00E-07
Status	PASS	PASS	PASS	PASS	PASS

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

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Specification MIN

Common Mode Rejection Ratio (dB)

1.30E+02
1.20E+02
1.10E+02
1.00E+02
9.00E+01
8.00E+01
7.00E+01
6.00E+01

0 20 40 60 80 100 120 140 160 180 200

Total Dose (krad(Si))

Figure 5.7. Plot of Common Mode Rejection Ratio (dB) versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values 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 Common Mode Rejection Ratio (dB) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Common Mode Rejection Ratio (dB)	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	1.18E+02	1.17E+02	1.16E+02	1.15E+02	1.15E+02
24	1.11E+02	1.11E+02	1.11E+02	1.10E+02	1.10E+02
25	1.15E+02	1.14E+02	1.14E+02	1.13E+02	1.13E+02
41	1.22E+02	1.19E+02	1.19E+02	1.18E+02	1.17E+02
42	1.17E+02	1.16E+02	1.15E+02	1.14E+02	1.14E+02
62	1.15E+02	1.14E+02	1.14E+02	1.13E+02	1.12E+02
102	1.19E+02	1.18E+02	1.17E+02	1.16E+02	1.15E+02
105	1.13E+02	1.11E+02	1.11E+02	1.10E+02	1.09E+02
122	1.24E+02	1.21E+02	1.20E+02	1.18E+02	1.16E+02
125	1.21E+02	1.20E+02	1.18E+02	1.16E+02	1.14E+02
142	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02
152	1.24E+02	1.24E+02	1.24E+02	1.24E+02	1.24E+02
Biased Statistics					
Average Biased	1.17E+02	1.16E+02	1.15E+02	1.14E+02	1.13E+02
Std Dev Biased	3.81E+00	3.19E+00	3.07E+00	2.66E+00	2.66E+00
Ps90%/90% (+KTL) Biased	1.27E+02	1.24E+02	1.23E+02	1.22E+02	1.21E+02
Ps90%/90% (-KTL) Biased	1.06E+02	1.07E+02	1.07E+02	1.07E+02	1.06E+02
Un-Biased Statistics					
Average Un-Biased	1.18E+02	1.17E+02	1.16E+02	1.15E+02	1.13E+02
Std Dev Un-Biased	4.31E+00	4.16E+00	3.82E+00	3.44E+00	2.95E+00
Ps90%/90% (+KTL) Un-Biased	1.30E+02	1.28E+02	1.26E+02	1.24E+02	1.21E+02
Ps90%/90% (-KTL) Un-Biased	1.07E+02	1.06E+02	1.05E+02	1.05E+02	1.05E+02
Specification MIN	8.00E+01	8.00E+01	8.00E+01	8.00E+01	8.00E+01
Status	PASS	PASS	PASS	PASS	PASS

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

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Specification MIN

Power Supply Rejection Ratio (dB)

1.30E+02
1.20E+02
1.10E+02
1.00E+02
9.00E+01
8.00E+01
7.00E+01
6.00E+01

0 20 40 60 80 100 120 140 160 180 200

Total Dose (krad(Si))

Figure 5.8. Plot of Power Supply Rejection Ratio (dB) versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values as defined in the datasheet and/or test plan.

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

Table 5.8. Raw data for Power Supply Rejection Ratio (dB) versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Power Supply Rejection Ratio (dB)	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	1.22E+02	1.20E+02	1.19E+02	1.18E+02	1.17E+02
24	1.20E+02	1.18E+02	1.18E+02	1.18E+02	1.16E+02
25	1.30E+02	1.25E+02	1.24E+02	1.23E+02	1.21E+02
41	1.18E+02	1.17E+02	1.17E+02	1.16E+02	1.15E+02
42	1.18E+02	1.18E+02	1.17E+02	1.16E+02	1.15E+02
62	1.16E+02	1.16E+02	1.15E+02	1.14E+02	1.13E+02
102	1.19E+02	1.19E+02	1.17E+02	1.16E+02	1.15E+02
105	1.17E+02	1.16E+02	1.15E+02	1.13E+02	1.12E+02
122	1.26E+02	1.25E+02	1.23E+02	1.21E+02	1.18E+02
125	1.22E+02	1.20E+02	1.19E+02	1.17E+02	1.15E+02
142	1.18E+02	1.18E+02	1.18E+02	1.18E+02	1.18E+02
152	1.21E+02	1.21E+02	1.21E+02	1.21E+02	1.21E+02
Biased Statistics					
Average Biased	1.22E+02	1.20E+02	1.19E+02	1.18E+02	1.17E+02
Std Dev Biased	5.09E+00	3.37E+00	3.01E+00	2.80E+00	2.44E+00
Ps90%/90% (+KTL) Biased	1.36E+02	1.29E+02	1.27E+02	1.26E+02	1.24E+02
Ps90%/90% (-KTL) Biased	1.08E+02	1.11E+02	1.11E+02	1.11E+02	1.10E+02
Un-Biased Statistics					
Average Un-Biased	1.20E+02	1.19E+02	1.18E+02	1.16E+02	1.15E+02
Std Dev Un-Biased	3.96E+00	3.82E+00	3.32E+00	2.97E+00	2.33E+00
Ps90%/90% (+KTL) Un-Biased	1.31E+02	1.30E+02	1.27E+02	1.25E+02	1.21E+02
Ps90%/90% (-KTL) Un-Biased	1.09E+02	1.09E+02	1.09E+02	1.08E+02	1.08E+02
Specification MIN	8.00E+01	8.00E+01	8.00E+01	8.00E+01	8.00E+01
Status	PASS	PASS	PASS	PASS	PASS

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Specification MIN

Large Signal Voltage Gain (V/mV), Vo=+/-10V, Vs=+/-15V, Rl=2KΩ

1.20E+03
1.00E+03
8.00E+02
6.00E+02
4.00E+02
2.00E+02
0.00E+00

0 20 40 60 80 100 120 140 160 180 200

Total Dose (krad(Si))

Figure 5.9. Plot of Large Signal Voltage Gain (V/mV), Vo=+/-10V, Vs=+/-15V, Rl=2KΩ versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values as defined in the datasheet and/or test plan.

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

Table 5.9. Raw data for Large Signal Voltage Gain (V/mV), Vo=+/-10V, Vs=+/-15V, Rl=2KΩ versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Large Signal Voltage Gain (V/mV), Vo=+/-10V, Vs=+/-15V, Rl=2KΩ	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	9.72E+02	9.18E+02	7.78E+02	7.54E+02	6.60E+02
24	1.03E+03	8.08E+02	7.64E+02	7.54E+02	6.86E+02
25	9.23E+02	9.42E+02	8.77E+02	7.58E+02	7.57E+02
41	9.75E+02	9.91E+02	8.02E+02	7.69E+02	6.82E+02
42	1.11E+03	1.00E+03	7.98E+02	6.97E+02	6.89E+02
62	1.21E+03	8.97E+02	7.76E+02	8.22E+02	5.17E+02
102	9.02E+02	1.29E+03	8.33E+02	7.78E+02	5.67E+02
105	1.01E+03	8.71E+02	6.78E+02	6.02E+02	5.42E+02
122	1.06E+03	8.20E+02	8.42E+02	6.77E+02	5.31E+02
125	1.00E+03	9.61E+02	7.25E+02	6.31E+02	5.13E+02
142	8.59E+02	9.56E+02	9.83E+02	9.82E+02	1.01E+03
152	1.03E+03	1.01E+03	1.03E+03	1.01E+03	1.09E+03
Biased Statistics					
Average Biased	1.00E+03	9.33E+02	8.04E+02	7.47E+02	6.95E+02
Std Dev Biased	7.11E+01	7.78E+01	4.37E+01	2.81E+01	3.65E+01
Ps90%/90% (+KTL) Biased	1.20E+03	1.15E+03	9.24E+02	8.24E+02	7.95E+02
Ps90%/90% (-KTL) Biased	8.06E+02	7.19E+02	6.84E+02	6.69E+02	5.95E+02
Un-Biased Statistics					
Average Un-Biased	1.04E+03	9.68E+02	7.71E+02	7.02E+02	5.34E+02
Std Dev Un-Biased	1.14E+02	1.87E+02	7.04E+01	9.46E+01	2.17E+01
Ps90%/90% (+KTL) Un-Biased	1.35E+03	1.48E+03	9.64E+02	9.61E+02	5.93E+02
Ps90%/90% (-KTL) Un-Biased	7.26E+02	4.55E+02	5.78E+02	4.42E+02	4.74E+02
Specification MIN	5.00E+01	5.00E+01	5.00E+01	5.00E+01	2.50E+01
Status	PASS	PASS	PASS	PASS	PASS

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

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Specification MIN

Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ

1.50E+01
1.40E+01
1.30E+01
1.20E+01
1.10E+01
1.00E+01
9.00E+00
8.00E+00
7.00E+00
6.00E+00

0 20 40 60 80 100 120 140 160 180 200

Total Dose (krad(Si))

Figure 5.10. Plot of Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values as defined in the datasheet and/or test plan.

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

Table 5.10. Raw data for Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
24	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
25	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
41	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
42	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
62	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
102	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
105	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
122	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
125	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
142	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
152	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
Biased Statistics					
Average Biased	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
Std Dev Biased	0.00E+00	1.99E-15	1.99E-15	1.99E-15	5.48E-03
Ps90%/90% (+KTL) Biased	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
Ps90%/90% (-KTL) Biased	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
Un-Biased Statistics					
Average Un-Biased	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
Std Dev Un-Biased	5.48E-03	5.48E-03	8.37E-03	5.48E-03	8.37E-03
Ps90%/90% (+KTL) Un-Biased	1.37E+01	1.37E+01	1.37E+01	1.37E+01	1.38E+01
Ps90%/90% (-KTL) Un-Biased	1.36E+01	1.37E+01	1.37E+01	1.37E+01	1.37E+01
Specification MIN	1.00E+01	1.00E+01	1.00E+01	1.00E+01	1.00E+01
Status	PASS	PASS	PASS	PASS	PASS

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

Average Biased | Average Un-Biased | Ps90%/90% (+KTL) Biased | Ps90%/90% (+KTL) Un-Biased | Specification MAX

Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ

-6.00E+00, -7.00E+00, -8.00E+00, -9.00E+00, -1.00E+01, -1.10E+01, -1.20E+01, -1.30E+01, -1.40E+01

0 20 40 60 80 100 120 140 160 180 200

Total Dose (krad(Si))

Figure 5.11. Plot of Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values as defined in the datasheet and/or test plan.

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

Table 5.11. Raw data for Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
24	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
25	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
41	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
42	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
62	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
102	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
105	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
122	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
125	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
142	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
152	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
Biased Statistics					
Average Biased	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
Std Dev Biased	4.47E-03	5.48E-03	5.48E-03	5.48E-03	7.07E-03
Ps90%/90% (+KTL) Biased	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
Ps90%/90% (-KTL) Biased	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
Un-Biased Statistics					
Average Un-Biased	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
Std Dev Un-Biased	5.48E-03	0.00E+00	0.00E+00	4.47E-03	5.48E-03
Ps90%/90% (+KTL) Un-Biased	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
Ps90%/90% (-KTL) Un-Biased	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01	-1.36E+01
Specification MAX	-1.00E+01	-1.00E+01	-1.00E+01	-1.00E+01	-1.00E+01
Status	PASS	PASS	PASS	PASS	PASS

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

Average Biased
Average Un-Biased
Ps90%/90% (-KTL) Biased
Ps90%/90% (-KTL) Un-Biased
Specification MIN

Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ

1.45E+01
1.40E+01
1.35E+01
1.30E+01
1.25E+01
1.20E+01
1.15E+01

0 20 40 60 80 100 120 140 160 180 200

Total Dose (krad(Si))

Figure 5.12. Plot of Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values as defined in the datasheet and/or test plan.

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

Table 5.12. Raw data for Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
24	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
25	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
41	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
42	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
62	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
102	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
105	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
122	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
125	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
142	1.39E+01	1.39E+01	1.39E+01	1.39E+01	1.39E+01
152	1.39E+01	1.39E+01	1.39E+01	1.39E+01	1.39E+01
Biased Statistics					
Average Biased	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
Std Dev Biased	1.99E-15	0.00E+00	1.99E-15	0.00E+00	0.00E+00
Ps90%/90% (+KTL) Biased	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
Ps90%/90% (-KTL) Biased	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
Un-Biased Statistics					
Average Un-Biased	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
Std Dev Un-Biased	5.48E-03	5.48E-03	8.37E-03	5.48E-03	8.37E-03
Ps90%/90% (+KTL) Un-Biased	1.39E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
Ps90%/90% (-KTL) Un-Biased	1.39E+01	1.39E+01	1.39E+01	1.40E+01	1.40E+01
Specification MIN	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01
Status	PASS	PASS	PASS	PASS	PASS

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

Average Biased
Average Un-Biased
Ps90%/90% (+KTL) Biased
Ps90%/90% (+KTL) Un-Biased
Specification MAX

Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ

-1.15E+01
-1.20E+01
-1.25E+01
-1.30E+01
-1.35E+01
-1.40E+01
-1.45E+01

0 20 40 60 80 100 120 140 160 180 200

Total Dose (krad(Si))

Figure 5.13. Plot of Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ versus total dose. The data show no significant degradation with radiation. The solid diamonds are the average of measured data points from the biased sample (devices irradiated with an electrical bias) while the shaded diamonds are the average from the un-biased sample. The black lines show the effects on the data after application of the biased KTL statistics (solid and/or dashed lines) while the gray lines show the effects on the data after application of the unbiased KTL statistics (solid and/or dashed lines). The red dashed lines are the minimum and/or maximum specification values as defined in the datasheet and/or test plan.

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

Table 5.13. Raw data for Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ versus total dose, including the statistical analysis, specification and the status of the testing (pass/fail).

Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ	Total Dose (krad(Si))				
Device	0	20	50	100	200
1	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
24	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
25	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
41	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
42	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
62	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
102	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
105	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
122	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
125	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
142	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
152	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
Biased Statistics					
Average Biased	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
Std Dev Biased	0.00E+00	5.48E-03	5.48E-03	4.47E-03	1.99E-15
Ps90%/90% (+KTL) Biased	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
Ps90%/90% (-KTL) Biased	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
Un-Biased Statistics					
Average Un-Biased	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
Std Dev Un-Biased	4.47E-03	4.47E-03	4.47E-03	0.00E+00	4.47E-03
Ps90%/90% (+KTL) Un-Biased	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
Ps90%/90% (-KTL) Un-Biased	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01	-1.41E+01
Specification MAX	-1.20E+01	-1.20E+01	-1.20E+01	-1.20E+01	-1.20E+01
Status	PASS	PASS	PASS	PASS	PASS

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

6.0. Summary / Conclusions

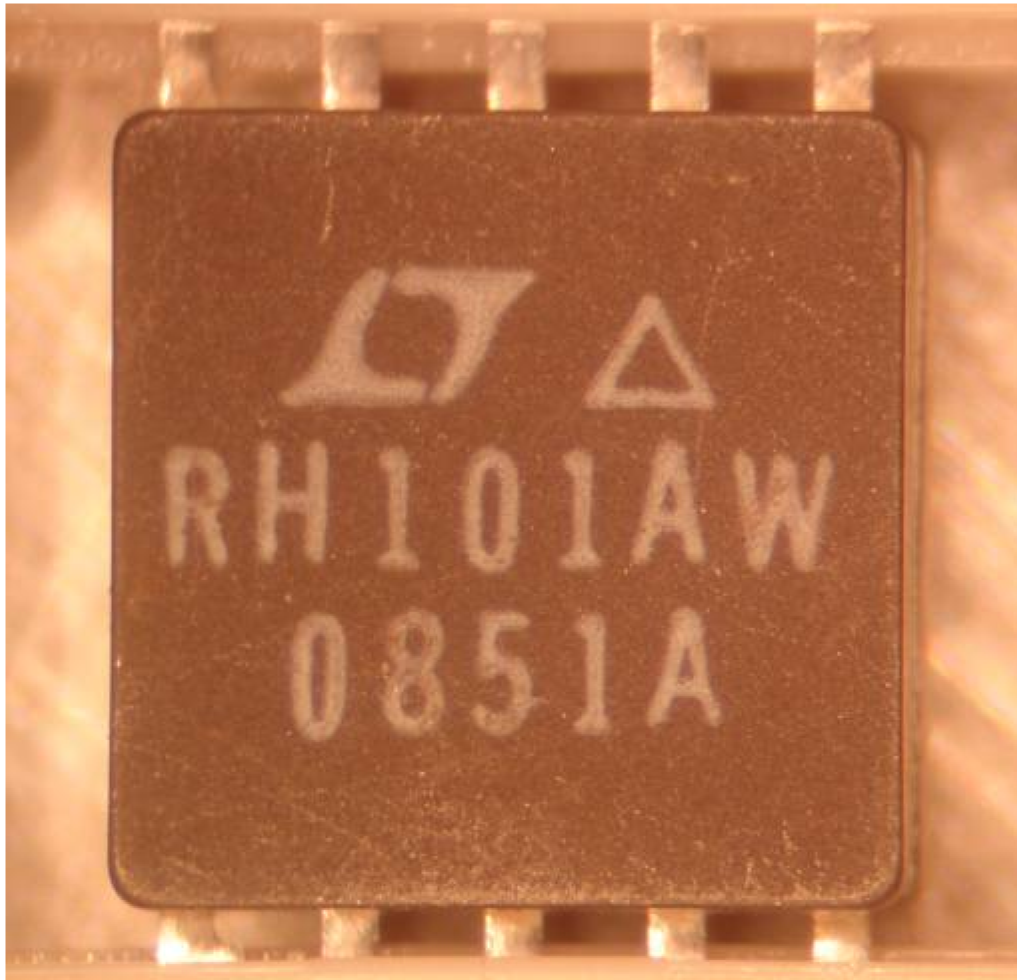
The total ionizing dose testing described in this final report was performed using the facilities at Radiation Assured Devices' Longmire Laboratories in Colorado Springs, CO. The high dose rate total ionizing dose (TID) source is a JLSA 84-21 irradiator modified to provide a panoramic exposure. The Co-60 rods are held in the base of the irradiator heavily shielded by lead, during the radiation 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 <1rad(Si)/s to a maximum of approximately 120rad(Si)/s, determined by the distance from the source.

The parametric data was obtained as "read and record" and all the raw data plus an attributes summary 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 the five-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 could be logged as an RLAT failure.

Based on these criteria, the RH101 operational amplifiers (with the traceability identified on the first page of this report) passed the RLAT to the maximum level tested of 200krad(Si) with no significant degradation to most of the measured parameters. Open loop gain exhibited some degradation with radiation, however it was not sufficient to cause the parameter to fall out of specification even after application of the KTL statistics.

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

Appendix A: Photograph of Sample Unit-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 RH101 Datasheet)

Biased Samples:

PIN Number	Function	Bias
1	N/C	N/C
2	COMP	N/C
3	-IN	To Pin 7 Via 10kΩ
4	+IN	To 8V Via 10kΩ
5	V-	-15V (decouple with 0.01µF)
6	N/C	N/C
7	OUT	To Pin 3 Via 10kΩ
8	V+	+15V (decouple with 0.01µF)
9	COMP	N/C
10	N/C	N/C

Unbiased Samples (All Pins Tied to Ground, Except No Connects):

PIN Number	Function	Bias
1	N/C	N/C
2	COMP	N/C
3	-IN	GND
4	+IN	GND
5	V-	GND
6	N/C	N/C
7	OUT	GND
8	V+	GND
9	COMP	N/C
10	N/C	N/C

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

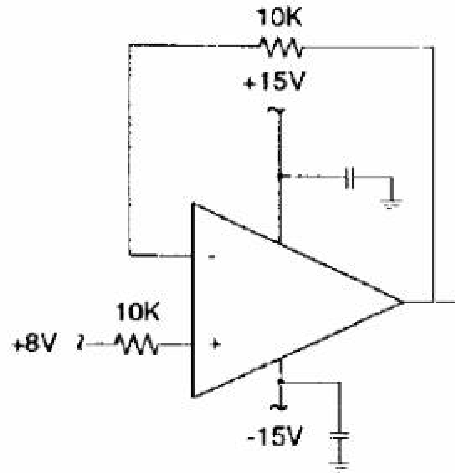


Figure B.1. Irradiation bias circuit for the units to be irradiated under electrical bias. This figure was extracted from the LINEAR TECHNOLOGY CORPORATION RH101A, OPERATIONAL AMPLIFIER SPEC NO. 05-08-5015 REV. L.

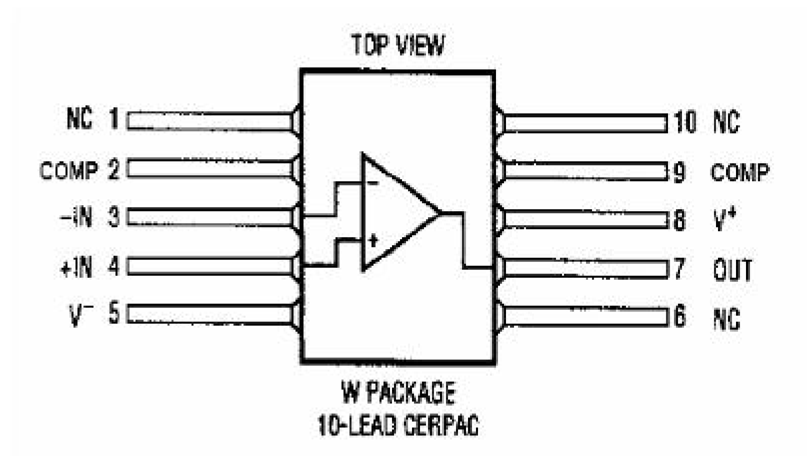


Figure B.2. W package drawing (for reference only). This figure was extracted from the LINEAR TECHNOLOGY CORPORATION RH101A, OPERATIONAL AMPLIFIER SPEC NO. 05-08-5015 REV. L.

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.

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

Table C.1. Measured parameters and test conditions for the RH101AW. Unless otherwise noted the conditions were selected to match the post-irradiation specifications. See LINEAR TECHNOLOGY CORPORATION RH101 Datasheet for the post irradiation test conditions and specifications.

Parameter	Test Conditions
Supply Current (Positive Supply), I_{CC}	V_S=±20
Supply Current (Negative Supply), I_{EE}	V_S=±20
Input Offset Voltage, V_{OS} (V)	V_S=±20, $R_S \leq$ 50kΩ
Input Offset Current, I_{OS} (A)	V_S=±20
Input Bias Current, Non-Inverting Input, I_{B+} (A)	V_S=±20, V_{CM}=0V
Input Bias Current, Inverting Input, I_{B-} (A)	V_S=±20, V_{CM}=0V
Common Mode Rejection Ratio, CMRR	V_S=±20, $R_S \leq$ 50kΩ, V_{CM} = ±15
Power Supply Rejection Ratio, PSRR	V_s = ±5V to ±20V $R_S \leq$ 50kΩ,
Large Signal Voltage Gain, A_{VOL}	V_S=±15, V_O = ±10V R_L=2kΩ
Maximum Output Voltage Swing, PostiveV_{OUT+1}	V_S=±15, R_L=2kΩ
Maximum Output Voltage Swing, Negative V_{OUT-1}	V_S=±15, R_L=2kΩ
Maximum Output Voltage Swing, PostiveV_{OUT+2}	V_S=±15, R_L=10kΩ
Maximum Output Voltage Swing, Negative V_{OUT-2}	V_S=±15, R_L=10kΩ

Note that the test conditions for PSRR and AVOL are slightly different than what is listed in the Linear Technology Datasheet due to probable typo's in the LT datasheet.

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

Table C.2. Measured parameters, pre-irradiation specifications and measurement resolution for the RH101AW.

Measured Parameter	Pre-Irradiation Specification	Measurement Precision/Resolution
Supply Current (Positive Supply), I_{CC}	3mA MAX	±8.71E-06A
Supply Current (Negative Supply), I_{EE}	3mA MAX	±1.09E-05A
Input Offset Voltage, V_{OS} (V)	2mV MAX	±3.65E-06V
Input Offset Current, I_{OS} (A)	10nA MAX	±6.06E-11A
Input Bias Current, I_{B} (A)	75nA MAX	±8.72E-10A
Common Mode Rejection Ratio, CMRR	80dB MIN	±1.27E+00dB
Power Supply Rejection Ratio, PSRR	80dB MIN	±8.59E-01dB
Large Signal Voltage Gain, A_{VOL}	50V/mV MIN	±1.87E+02V/mV
Maximum Output Voltage Swing, PostiveV_{OUT+1}	10V MIN	±1.0E-02V
Maximum Output Voltage Swing, Negative V_{OUT-1}	-10V MAX	±1.0E-02V
Maximum Output Voltage Swing, PostiveV_{OUT+2}	12V MIN	±1.0E-02V
Maximum Output Voltage Swing, Negative V_{OUT-2}	-12V MAX	±1.0E-02V

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

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

5.1 Positive Power Supply Current (A)
5.2 Negative Power Supply Current (A)
5.3 Input Offset Voltage (V)
5.4 Input Offset Current (A)
5.5 Positive Input Bias Current (A)
5.6 Negative Input Bias Current (A)
5.7 Common Mode Rejection Ratio (dB)
5.8 Power Supply Rejection Ratio (dB)
5.9 Large Signal Voltage Gain (V/mV), Vo=+/-10V, Vs=+/-15V, Rl=2KΩ
5.10 Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ
5.11 Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=2KΩ
5.12 Positive Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ
5.13 Negative Maximum Output Voltage Swing (V), Vs=+/-15V, Rl=10KΩ