Total Dose Radiation Test Report

MSK106RH

Radiation Hardened High Power Op Amp

January 3, 2005 – TID (First Test)
Updated on August 4, 2006
Updated on January 25, 2008 (Second Test)
March 18, 2010 TID (Third Test)
April 24, 2013 – TID (Fourth Test)
September 15, 2017 – TID (Fifth Test)
October 11, 2018 – TID (Sixth Test)
April 29, 2021 – TID (Seventh Test)

E. Davis
J. Dubose
J. Saucier

Anaren, Inc. – MSK Products

I. Introduction:

The total dose radiation test plan for the MSK106RH was developed to qualify the device as radiation hardened up to 100 Krads(Si). The testing was performed beyond 100 Krads(Si) to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the hybrid, but simply offers designers insight to the critical parameter-shifts beyond the specified total dose level.

MIL-STD-883 Method 1019.7 and ASTM F1892-06 were used as guidelines in the development and implementation of the total dose test plan for the MSK106RH.

II. Radiation Source:

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. Dosimetry was performed prior to device irradiation and the dose rate was determined to be 87.6 rads(Si)/sec. The total dose schedule can be found in Table I.

III. Test Setup:

All test samples were subjected to Group A Electrical Test in accordance with the device data sheet. In addition, all devices received 160 hours of burn-in per MIL-STD-883 Method 1015 and were electrically tested prior to irradiation. For test platform verification, two control devices were tested at 25°C.

The devices were vertically aligned with the radiation source and enclosed in a lead/aluminum container during irradiation. An operating voltage of +/-18 Volts was used for the bias condition. Four devices were kept under bias during irradiation. Four devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and were transported to the MSK automatic electrical test platform and tested IAW MSK device data sheet. Testing was performed on irradiated devices, as well as two control devices, at each total dose level. Electrical tests were completed within one hour of irradiation. Subsequent dosing was performed within two hours.

IV. Data:

All performance curves are averaged from the test results of the biased and unbiased devices respectively. If required, full test data can be obtained by contacting Anaren, Inc. - MSK Products.

V. Summary:

The devices performed well with respect to TID, qualifying to 100 Krads(Si) by the 99/90 statistical analysis of the test data.

Quiescent current decreased as testing progressed. Input bias current increased significantly as testing progressed. Both quiescent current and input bias current stayed within specification limits to 150 Krads(Si).

Positive and negative slew rate decreased, while Transition Times showed a slight increase as testing progressed, but stayed within pre-irradiation limits to 150 Krads(Si).

MSK106RH Biased/Unbiased Dose Rate Schedule

Dosimetry Equipment
Bruker Biospin # 0162

Irradiation Date
4/29/21

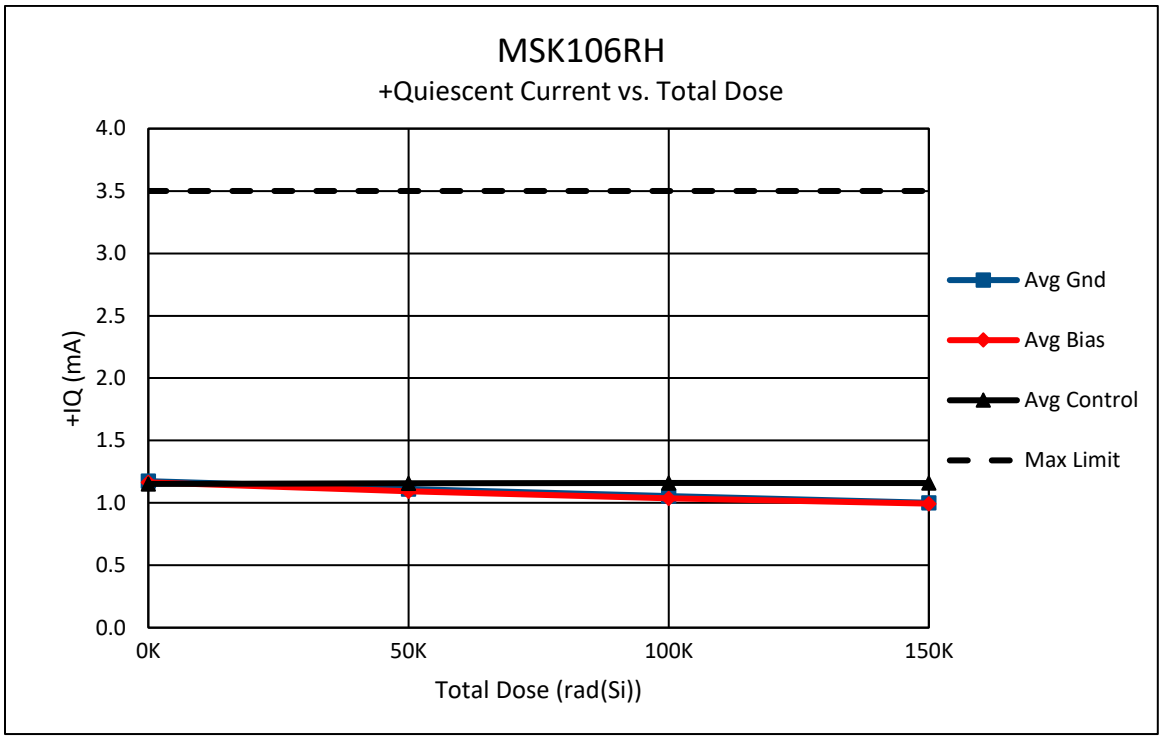
Exposure Length (min:sec)	Incremental Dose rads(Si)	Cumulative Dose rads(Si)
9:48	51,500	51,500
9:48	51,500	103,000
9:48	51,500	154,500

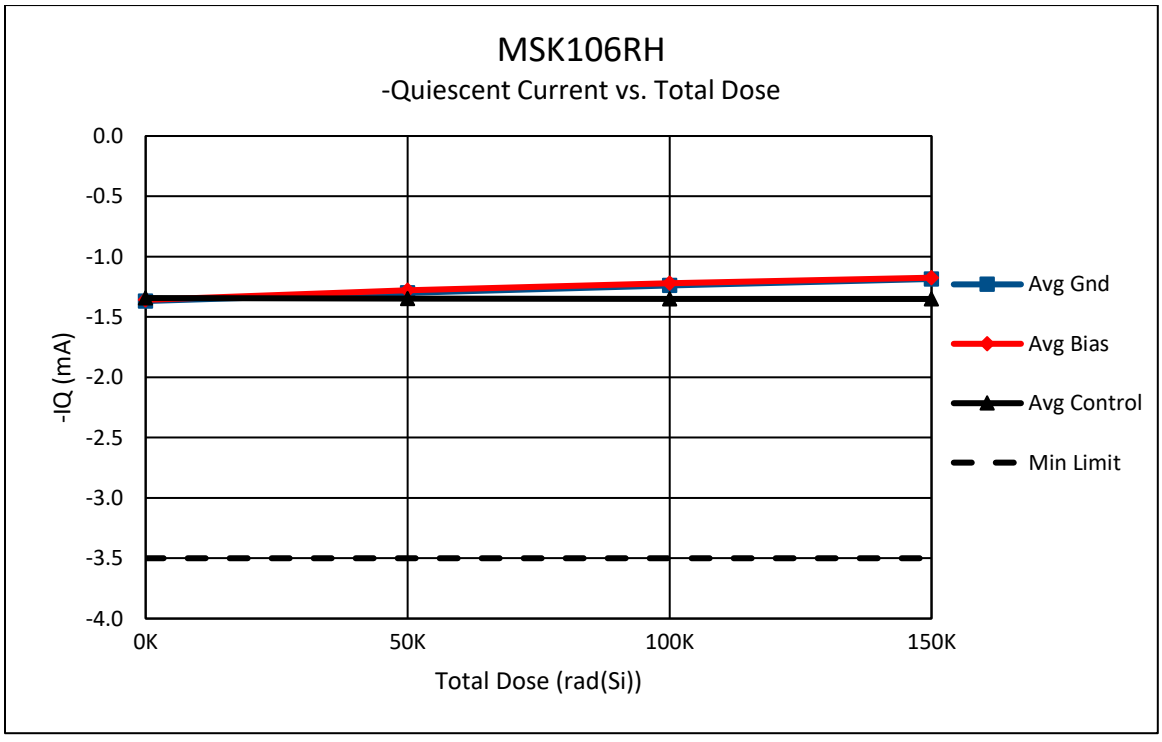
Biased S/N – 0089, 0091, 0092, 0093, 0094

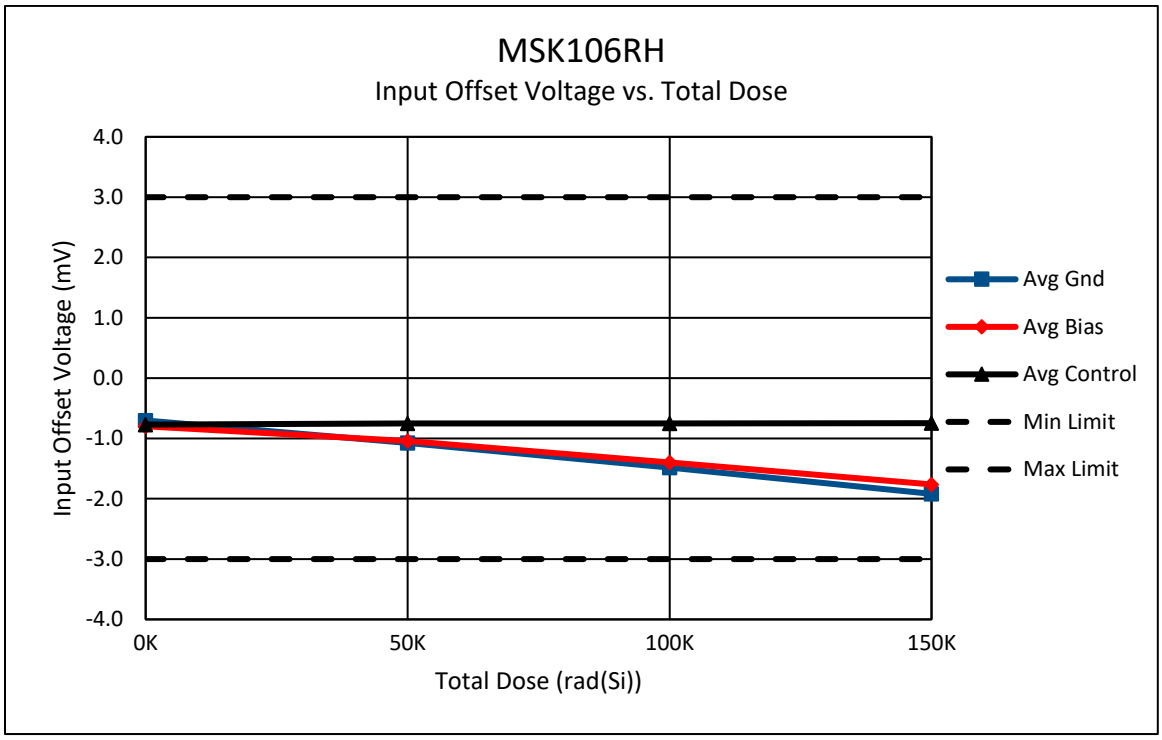
Unbiased S/N – 0095, 0096, 0097, 0098, 0099

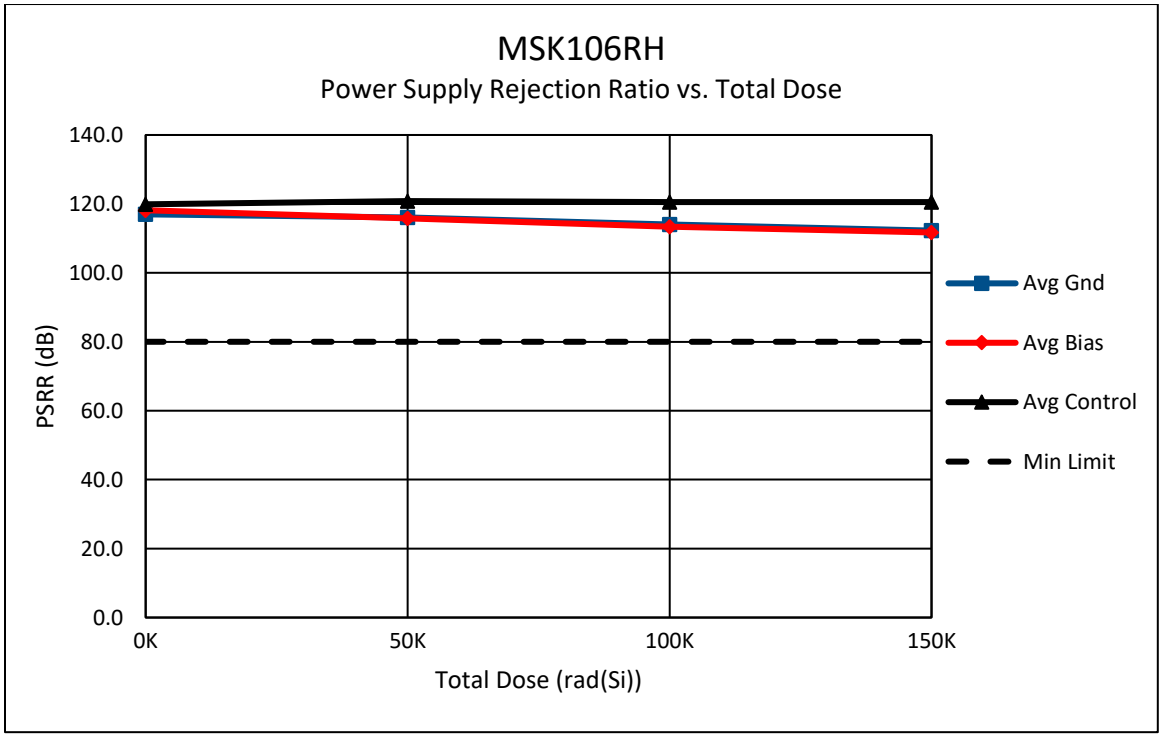
Table 1

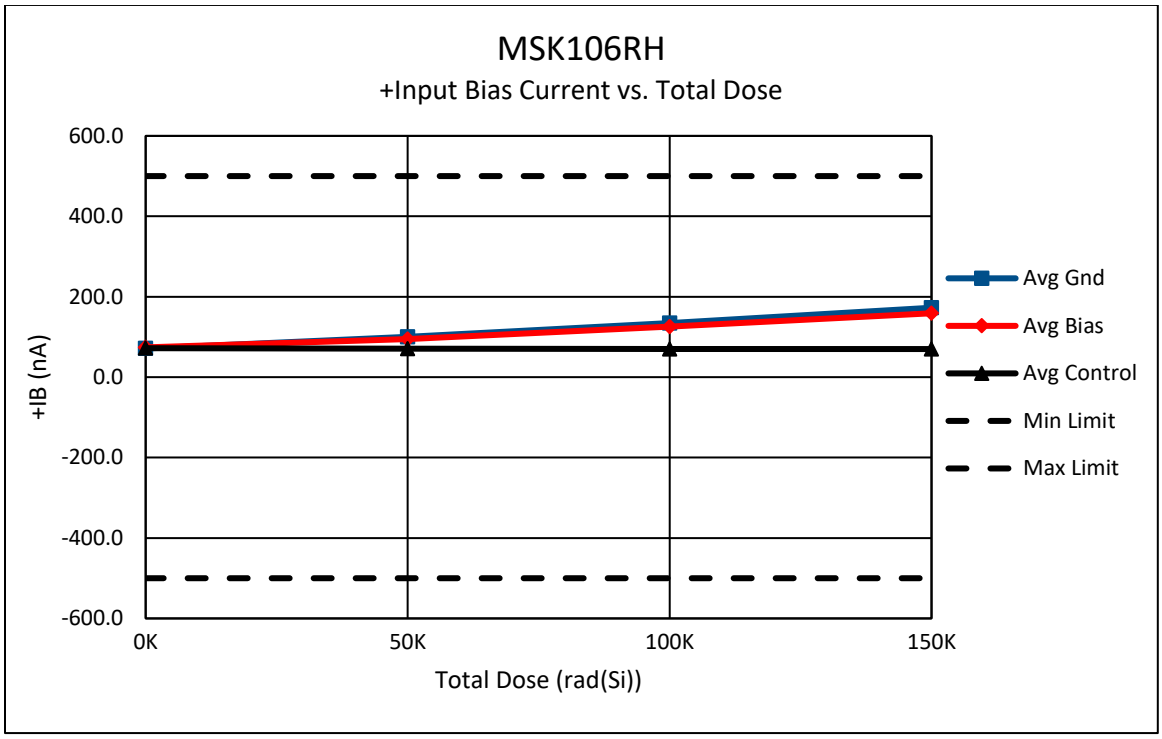
Dose Time, Incremental Dose and Total Cumulative Dose

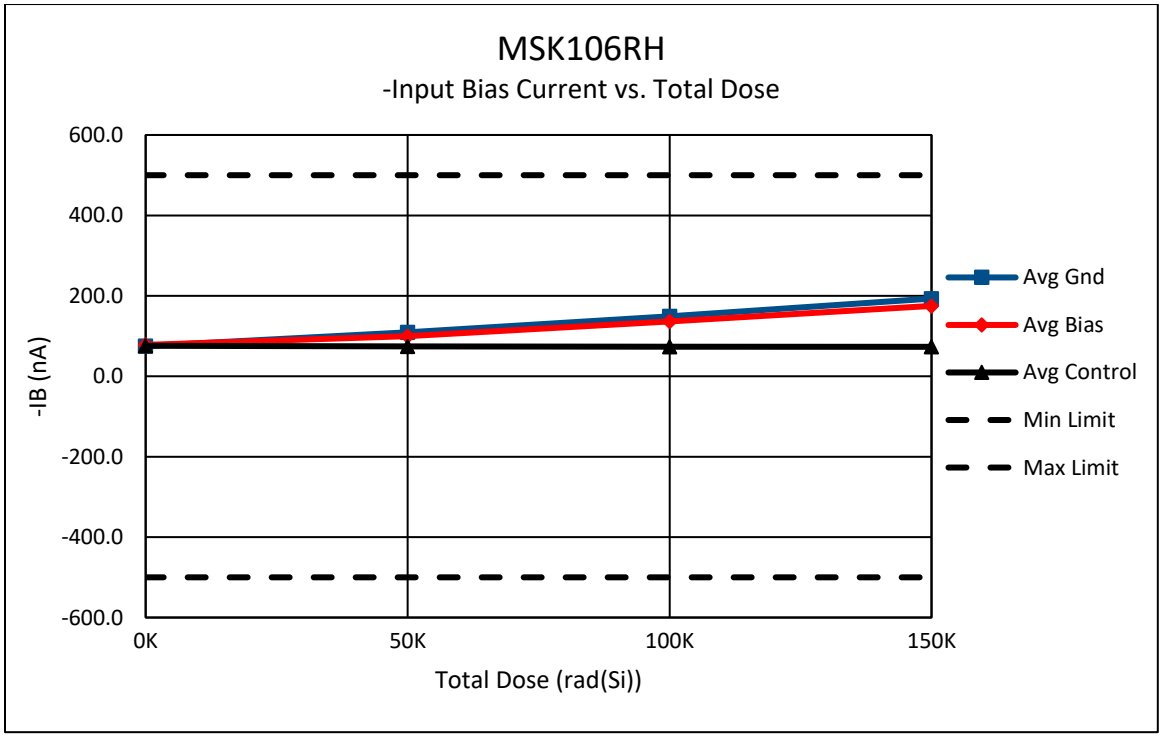

MSK106RH
+Quiescent Current vs. Total Dose
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
+IQ (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

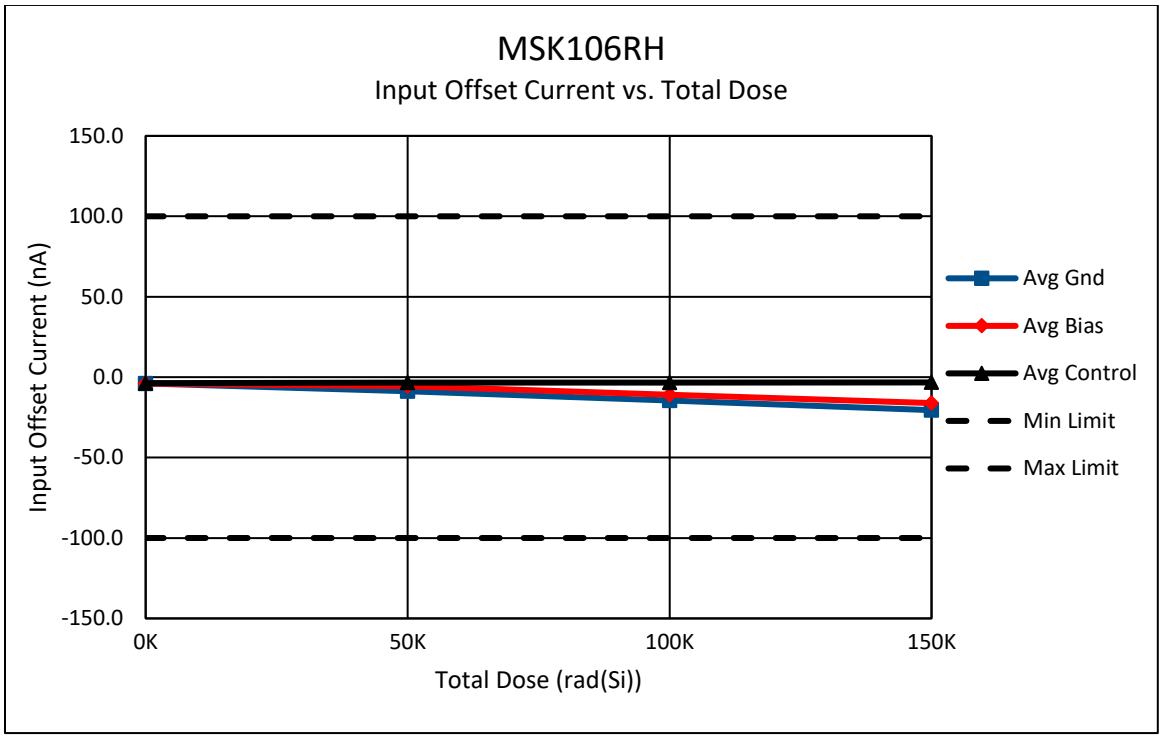

MSK106RH
-Quiescent Current vs. Total Dose
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-IQ (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

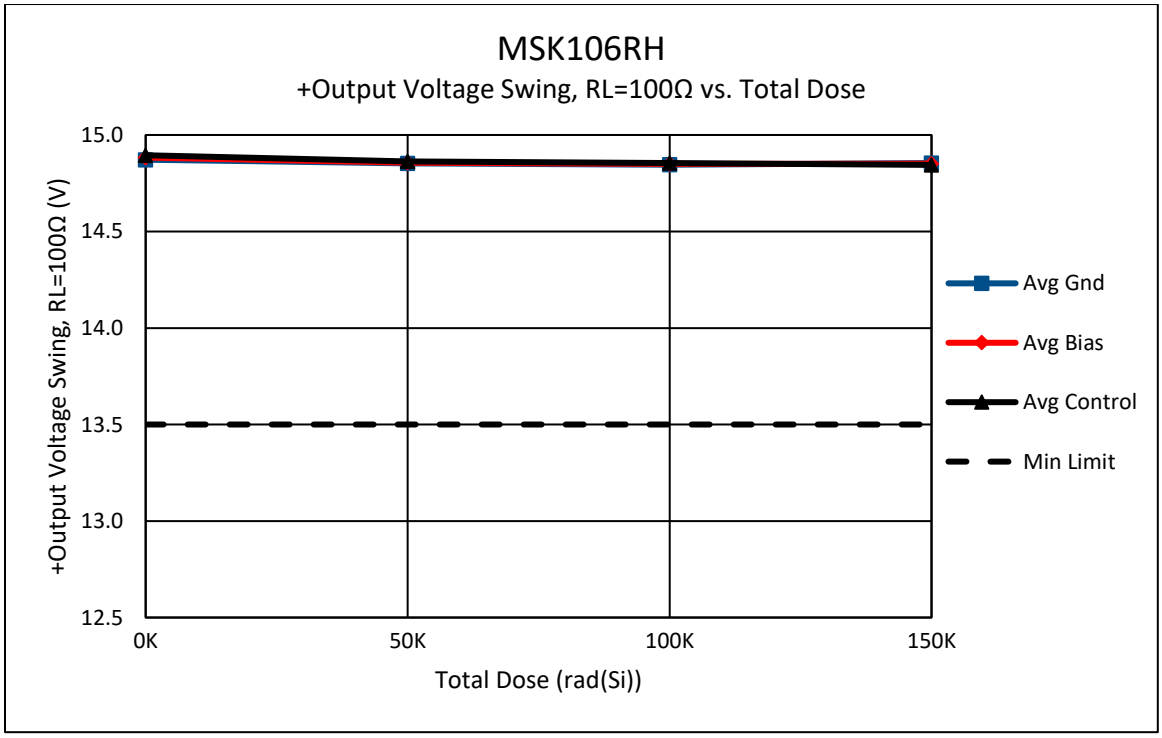

MSK106RH
Input Offset Voltage vs. Total Dose
Input Offset Voltage (mV)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

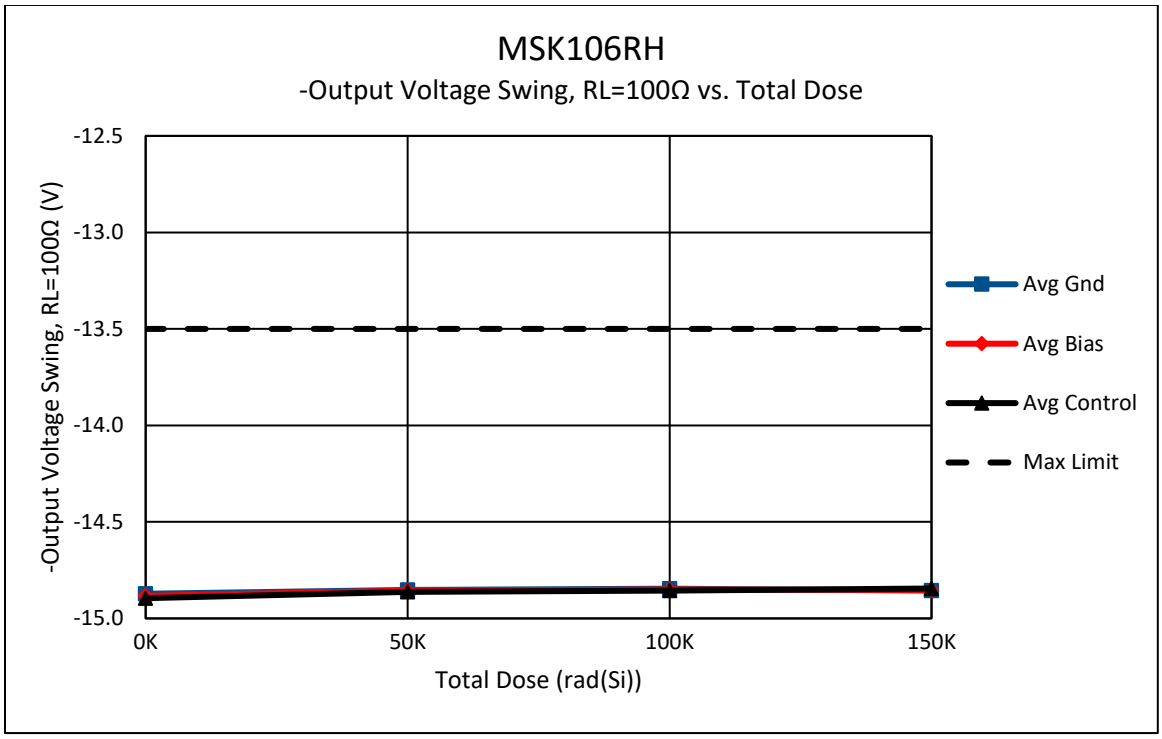

MSK106RH
Power Supply Rejection Ratio vs. Total Dose
PSRR (dB)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

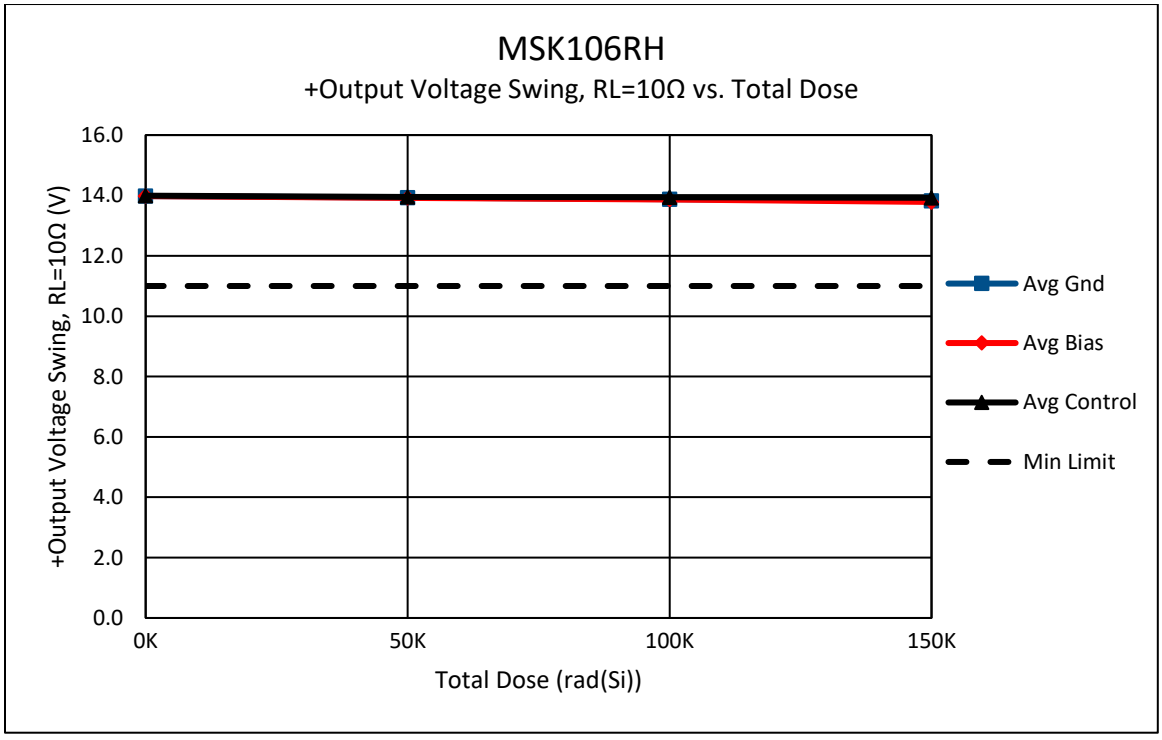

MSK106RH
+Input Bias Current vs. Total Dose
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
+IB (nA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

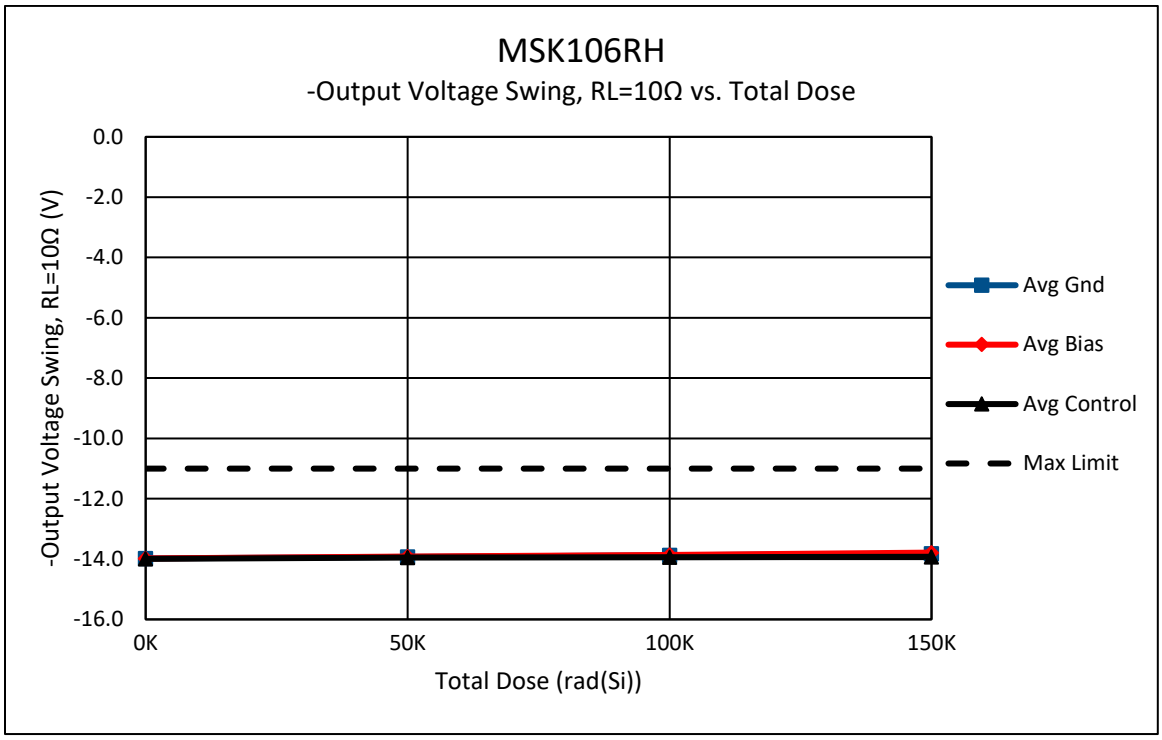

MSK106RH
-Input Bias Current vs. Total Dose
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
-IB (nA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

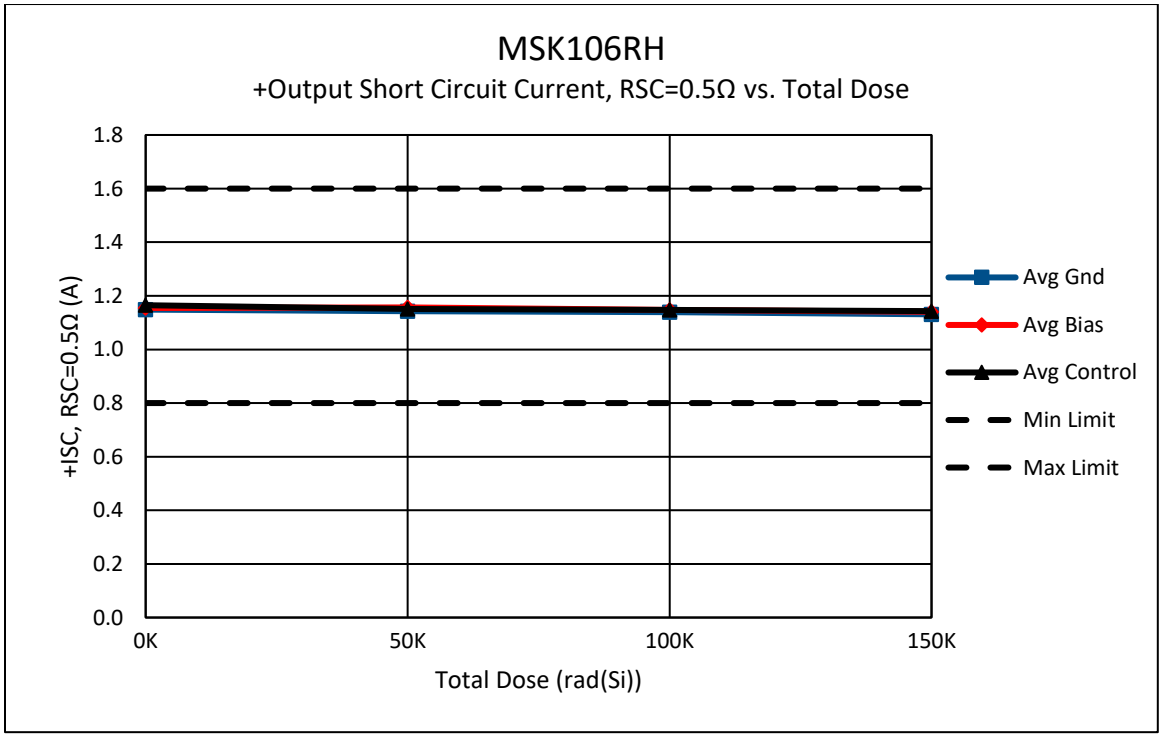

MSK106RH
Input Offset Current vs. Total Dose
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Input Offset Current (nA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

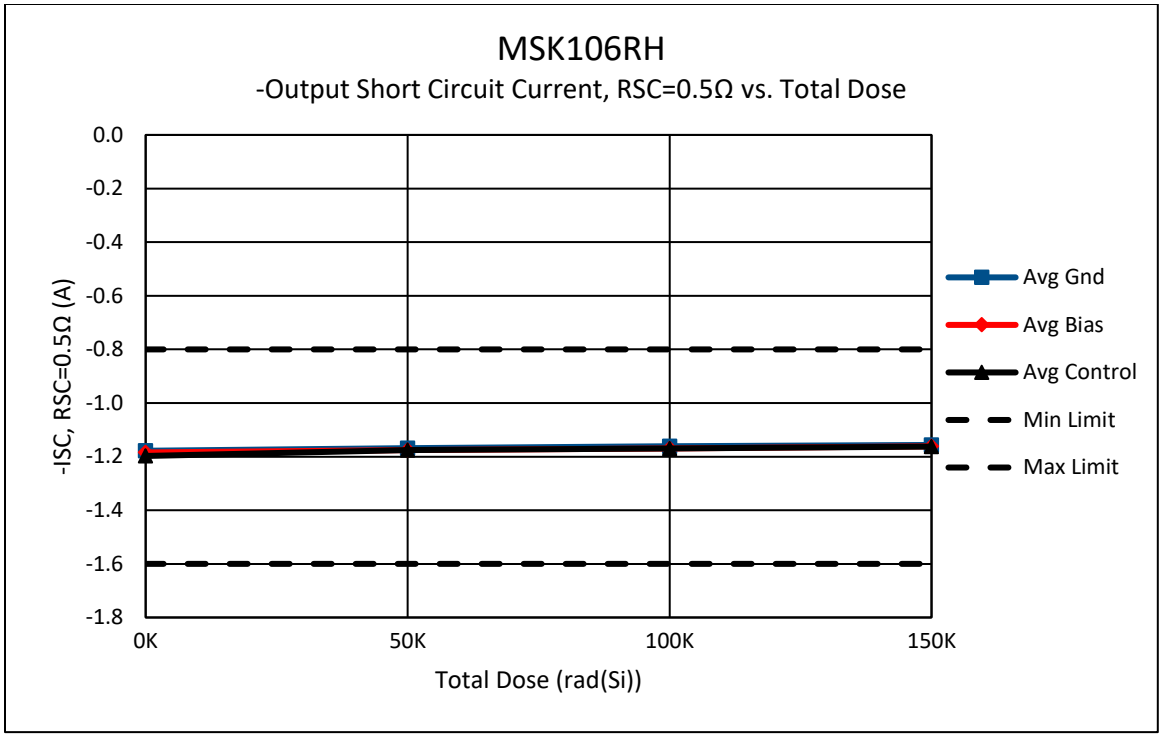

MSK106RH
+Output Voltage Swing, RL=100Ω vs. Total Dose
15.0
14.5
14.0
13.5
13.0
12.5
+Output Voltage Swing, RL=100Ω (V)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

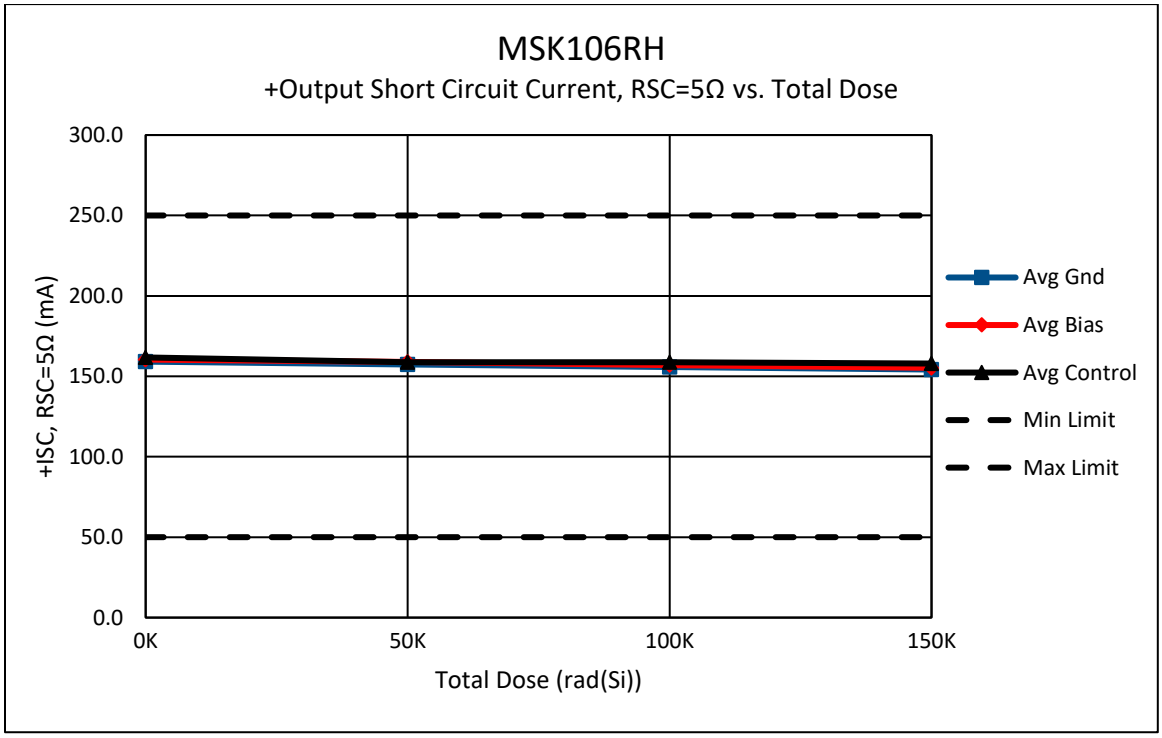

MSK106RH
-Output Voltage Swing, RL=100Ω vs. Total Dose
-Output Voltage Swing, RL=100Ω (V)
-12.5
-13.0
-13.5
-14.0
-14.5
-15.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

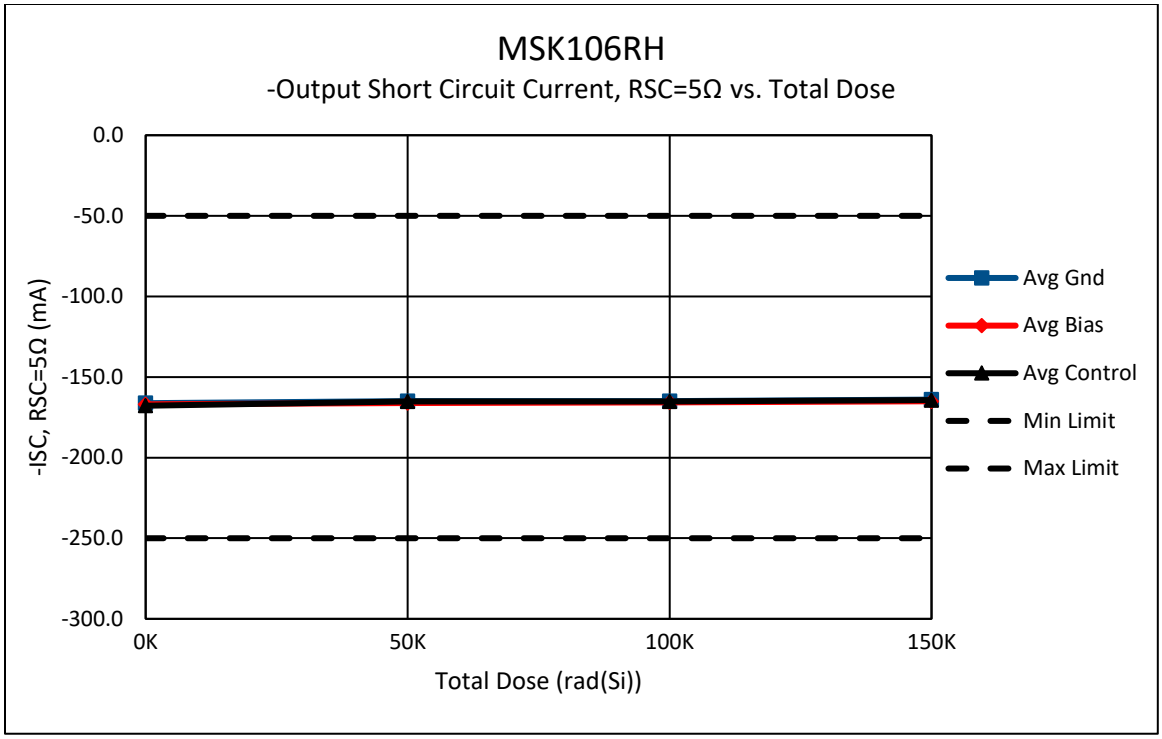

MSK106RH
+Output Voltage Swing, RL=10Ω vs. Total Dose
+Output Voltage Swing, RL=10Ω (V)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

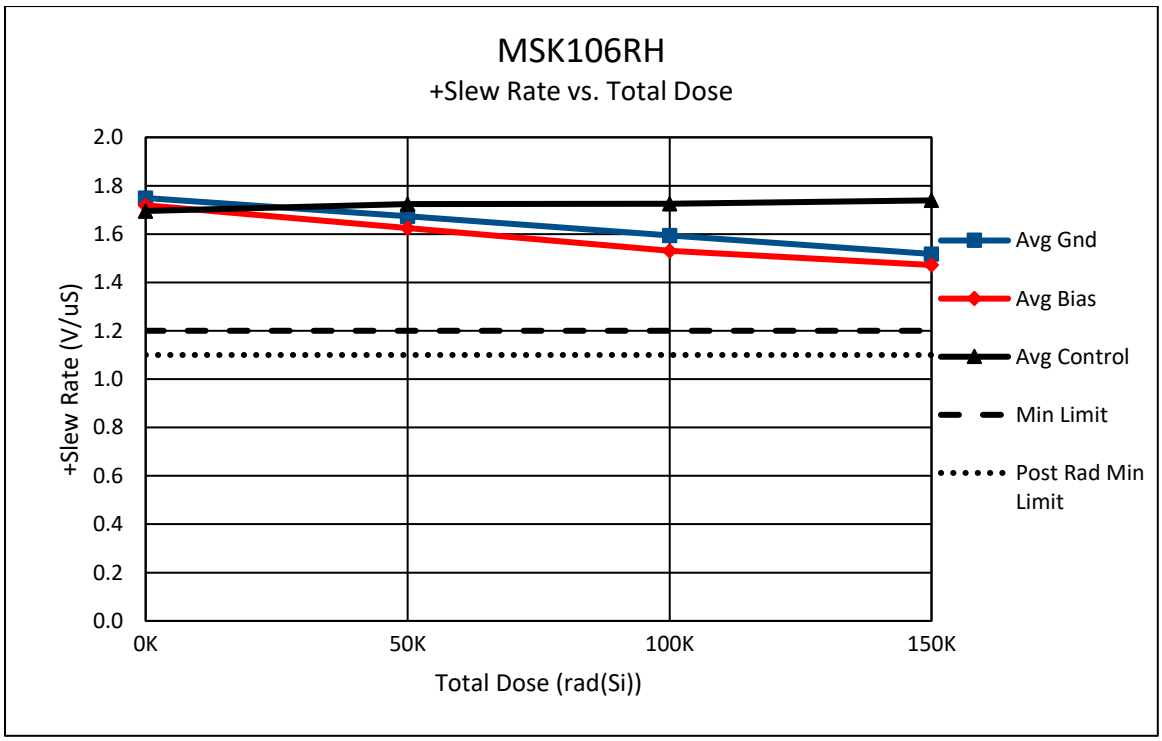

MSK106RH
-Output Voltage Swing, RL=10Ω vs. Total Dose
-Output Voltage Swing, RL=10Ω (V)
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

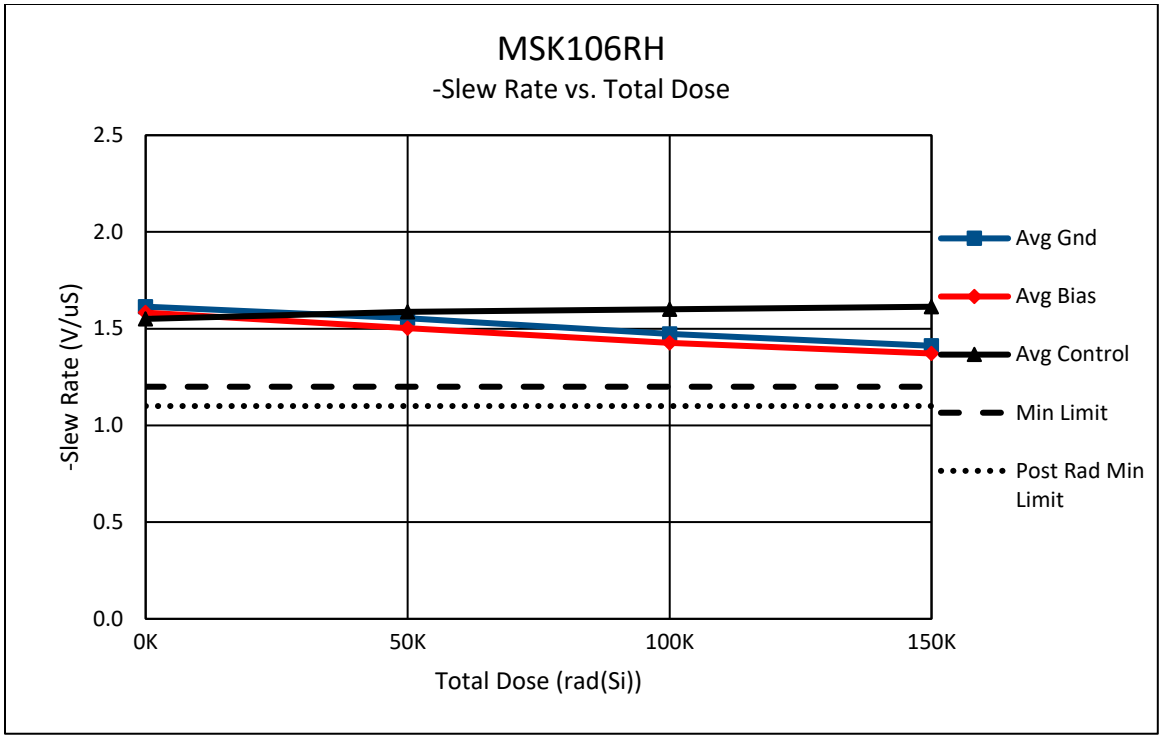

MSK106RH
+Output Short Circuit Current, RSC=0.5Ω vs. Total Dose
+ISC, RSC=0.5Ω (A)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

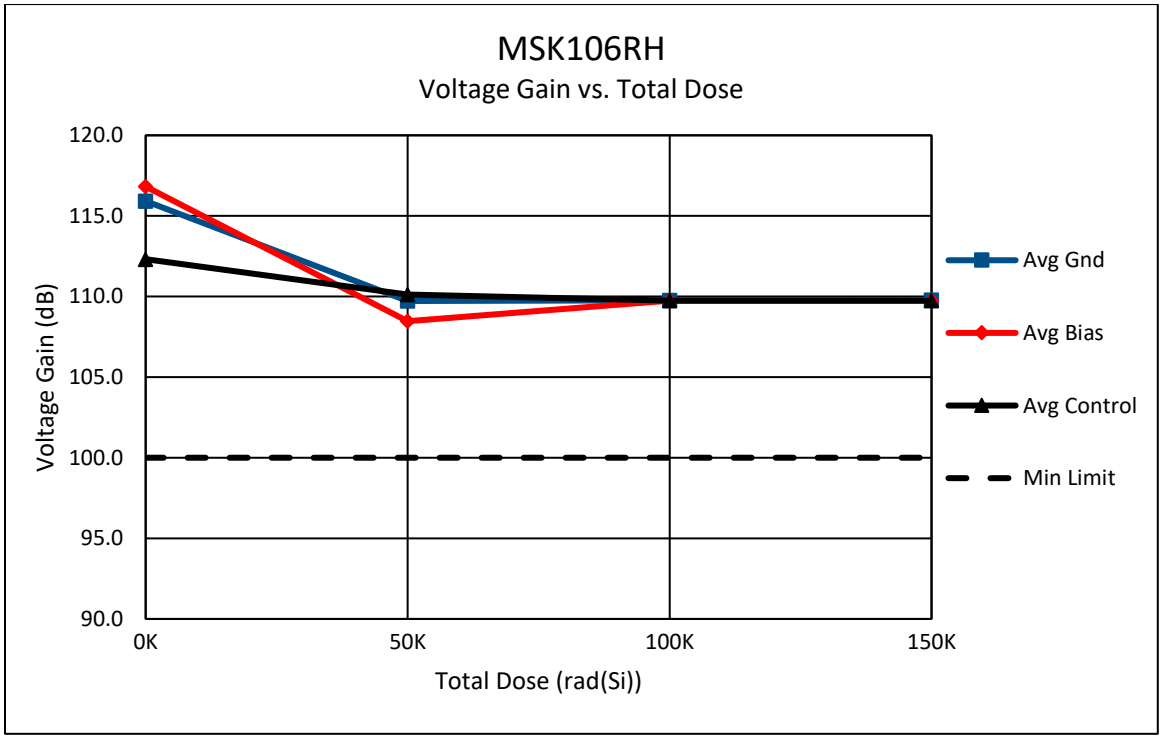

MSK106RH
-Output Short Circuit Current, RSC=0.5Ω vs. Total Dose
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-ISC, RSC=0.5Ω (A)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

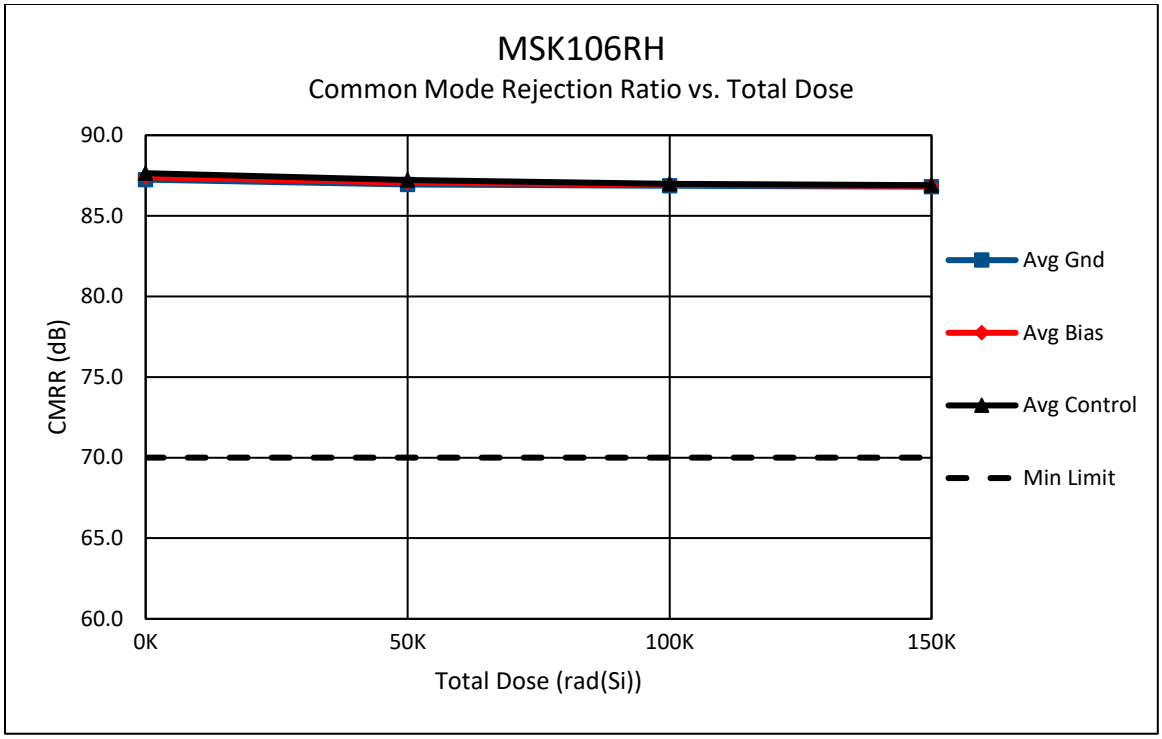

MSK106RH
+Output Short Circuit Current, RSC=5Ω vs. Total Dose
300.0
250.0
200.0
150.0
100.0
50.0
0.0
+ISC, RSC=5Ω (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

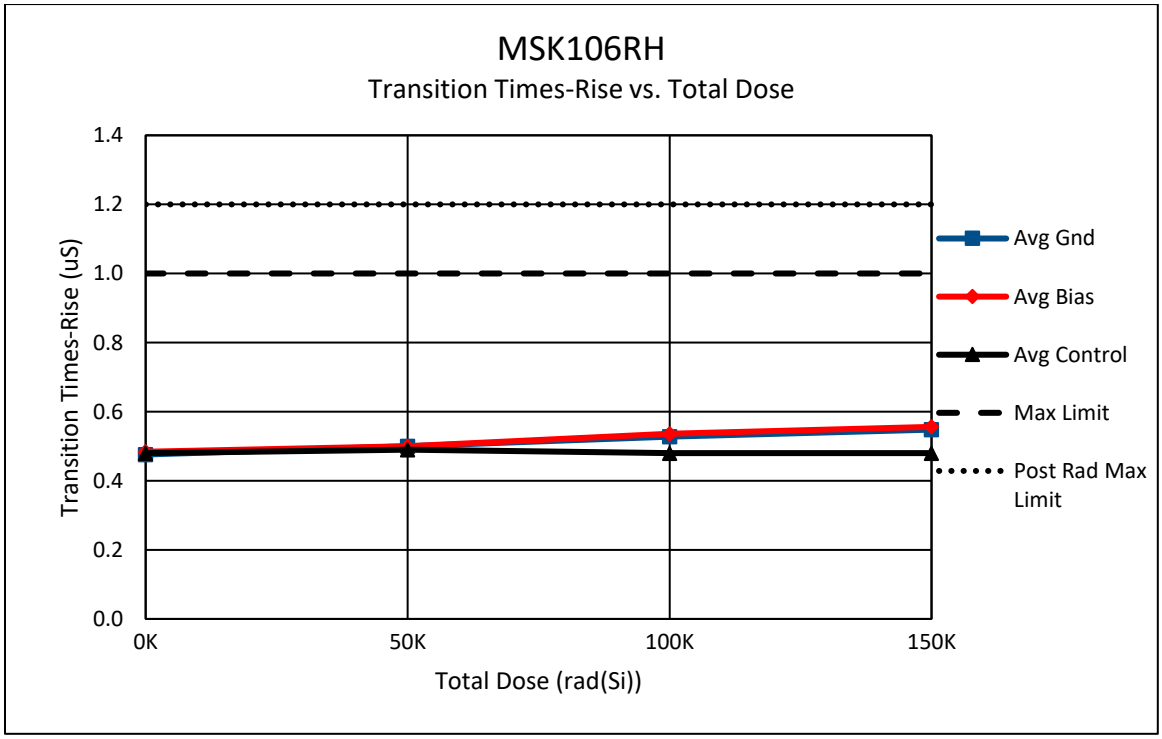

MSK106RH
-Output Short Circuit Current, RSC=5Ω vs. Total Dose
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
-300.0
-ISC, RSC=5Ω (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

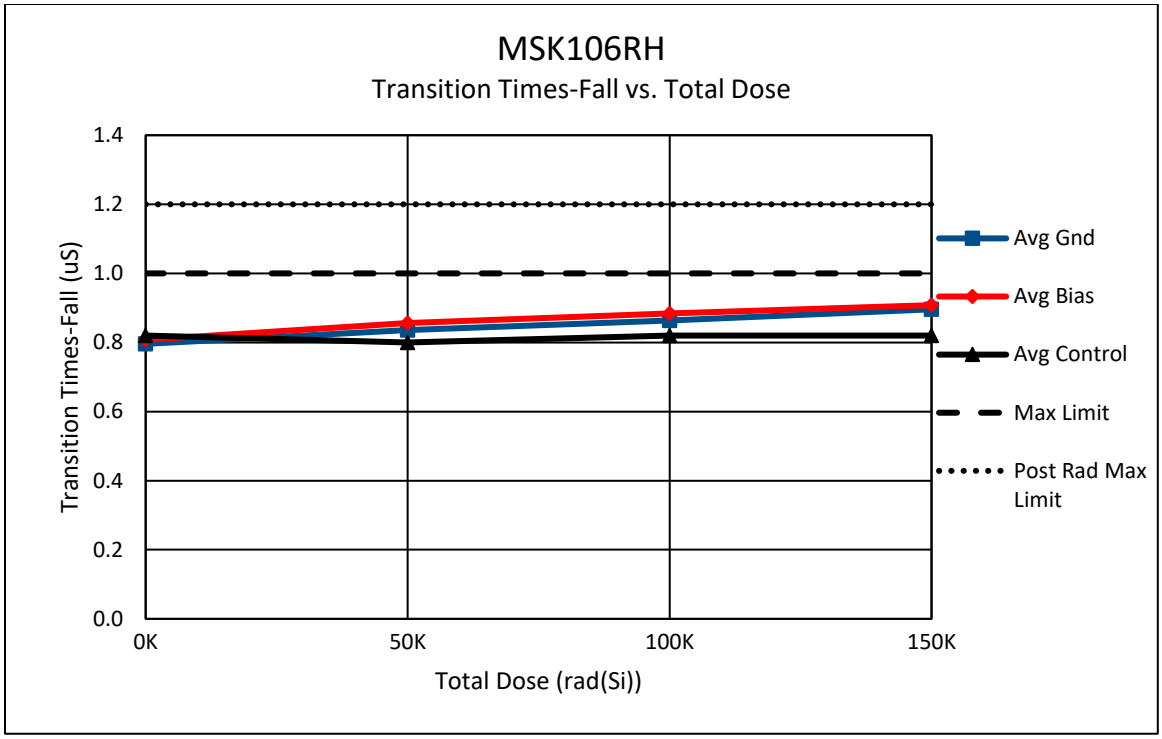

MSK106RH
+Slew Rate vs. Total Dose
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
+Slew Rate (V/uS)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Post Rad Min Limit

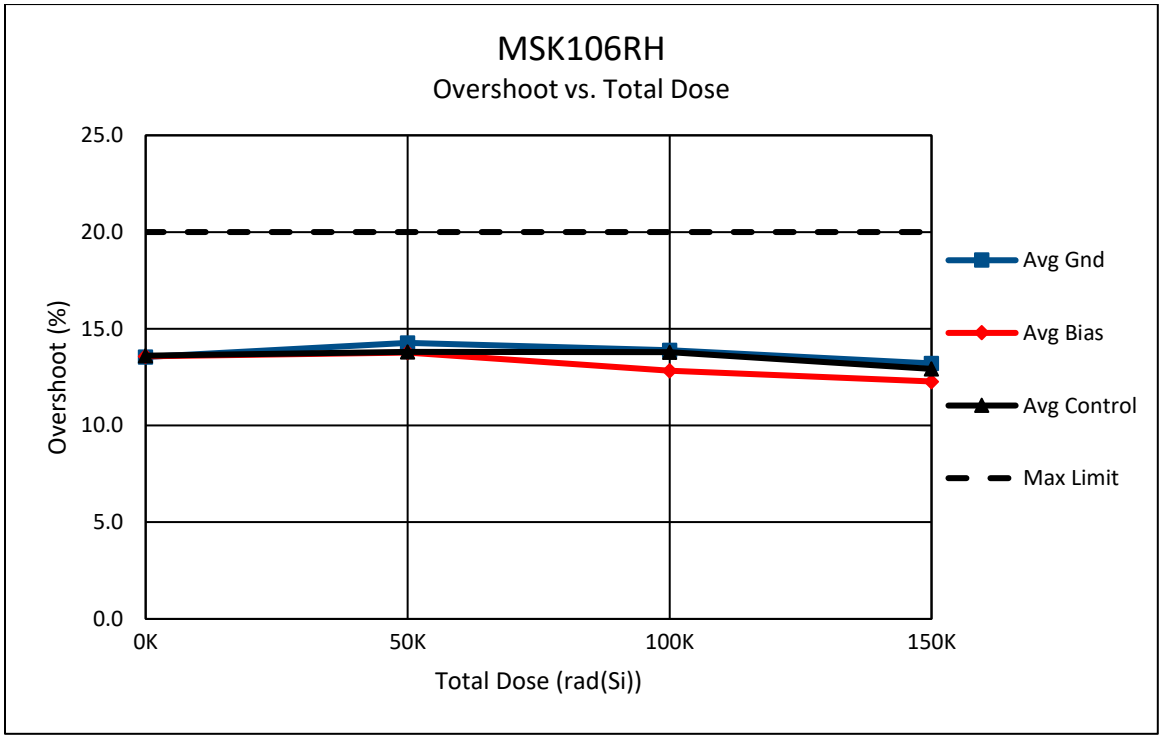

MSK106RH
-Slew Rate vs. Total Dose
2.5
2.0
1.5
1.0
0.5
0.0
-Slew Rate (V/uS)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Post Rad Min Limit


MSK106RH
Voltage Gain vs. Total Dose
120.0
115.0
110.0
105.0
100.0
95.0
90.0
Voltage Gain (dB)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit


MSK106RH
Common Mode Rejection Ratio vs. Total Dose
90.0
85.0
80.0
75.0
70.0
65.0
60.0
CMRR (dB)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit


MSK106RH
Transition Times-Rise vs. Total Dose
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Transition Times-Rise (uS)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit
Post Rad Max Limit


MSK106RH
Transition Times-Fall vs. Total Dose
Transition Times-Fall (uS)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit
Post Rad Max Limit


MSK106RH
Overshoot vs. Total Dose
Overshoot (%)
25.0
20.0
15.0
10.0
5.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

Total Dose Radiation Test Report

MSK106RH

Radiation Hardened High Power Op Amp

January 3, 2005 – TID (First Test)
Updated on August 4, 2006
Updated on January 25, 2008 (Second Test)
March 18, 2010 TID (Third Test)
April 24, 2013 – TID (Fourth Test)
September 15, 2017 – TID (Fifth Test)
October 11, 2018 – TID (Sixth Test)

B. Horton
F. Freytag

Anaren, Inc. – MSK Products

I. Introduction:

The total dose radiation test plan for the MSK106RH was developed to qualify the device as radiation hardened up to 100 Krads(Si). The testing was performed beyond 100 Krads(Si) to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the hybrid, but simply offers designers insight to the critical parameter-shifts beyond the specified total dose level.

MIL-STD-883 Method 1019.7 and ASTM F1892-06 were used as guidelines in the development and implementation of the total dose test plan for the MSK106RH.

II. Radiation Source:

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. Dosimetry was performed prior to device irradiation and the dose rate was determined to be 114.8 rads(Si)/sec. The total dose schedule can be found in Table I.

III. Test Setup:

All test samples were subjected to Group A Electrical Test in accordance with the device data sheet. In addition, all devices received 160 hours of burn-in per MIL-STD-883 Method 1015 and were electrically tested prior to irradiation. For test platform verification, two control devices were tested at 25°C.

The devices were vertically aligned with the radiation source and enclosed in a lead/aluminum container during irradiation. An operating voltage of +/-18 Volts was used for the bias condition. Four devices were kept under bias during irradiation. Four devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and were transported to the MSK automatic electrical test platform and tested IAW MSK device data sheet. Testing was performed on irradiated devices, as well as two control devices, at each total dose level. Electrical tests were completed within one hour of irradiation. Subsequent dosing was performed within two hours.

IV. Data:

All performance curves are averaged from the test results of the biased and unbiased devices respectively. If required, full test data can be obtained by contacting Anaren, Inc. - MSK Products.

V. Summary:

The devices performed well with respect to TID, qualifying to 100 Krads(Si) by the 99/90 statistical analysis of the test data.

Quiescent current decreased as testing progressed. Input bias current increased significantly as testing progressed. Both quiescent current and input bias current stayed within specification limits to 150 Krads(Si).

Positive and negative slew rate decreased, while Transition Times showed a slight increase as testing progressed, but stayed within pre-irradiation limits to 150 Krads(Si).

MSK106RH Biased/Unbiased Dose Rate Schedule

Dosimetry Equipment
Bruker Biospin # 0162

Irradiation Date
10/11/18

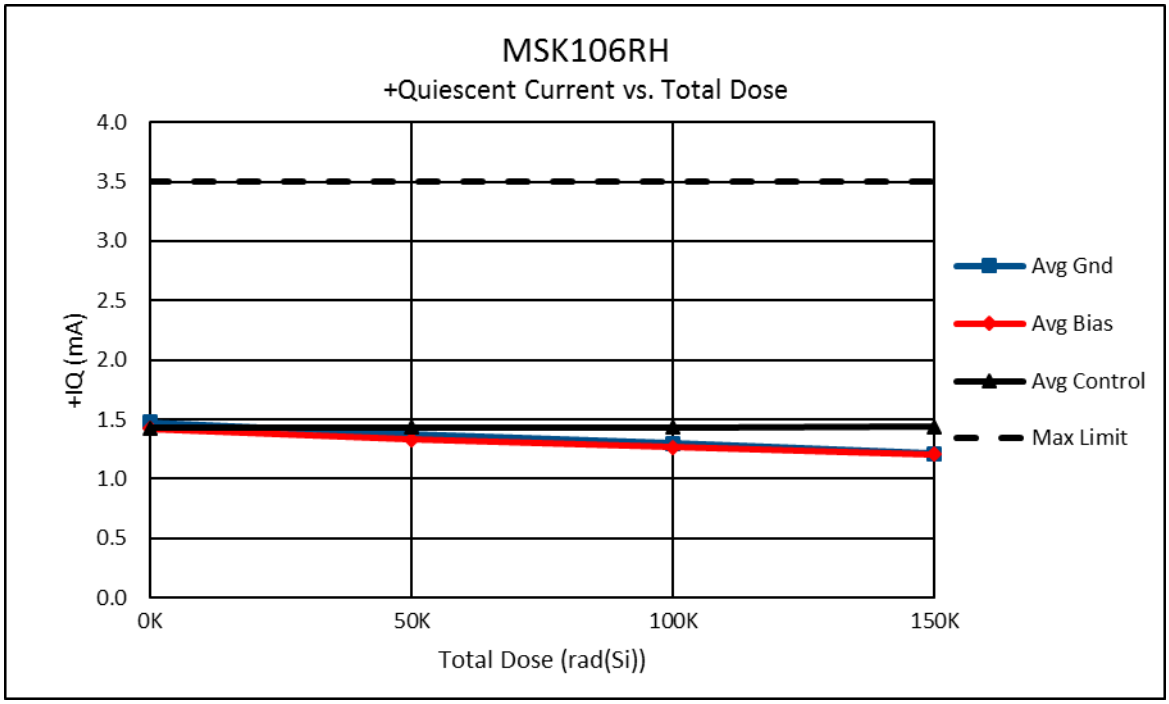
Exposure Length (min:sec)	Incremental Dose rads(Si)	Cumulative Dose rads(Si)
7:29	51,500	51,500
7:29	51,500	103,000
7:29	51,500	154,500

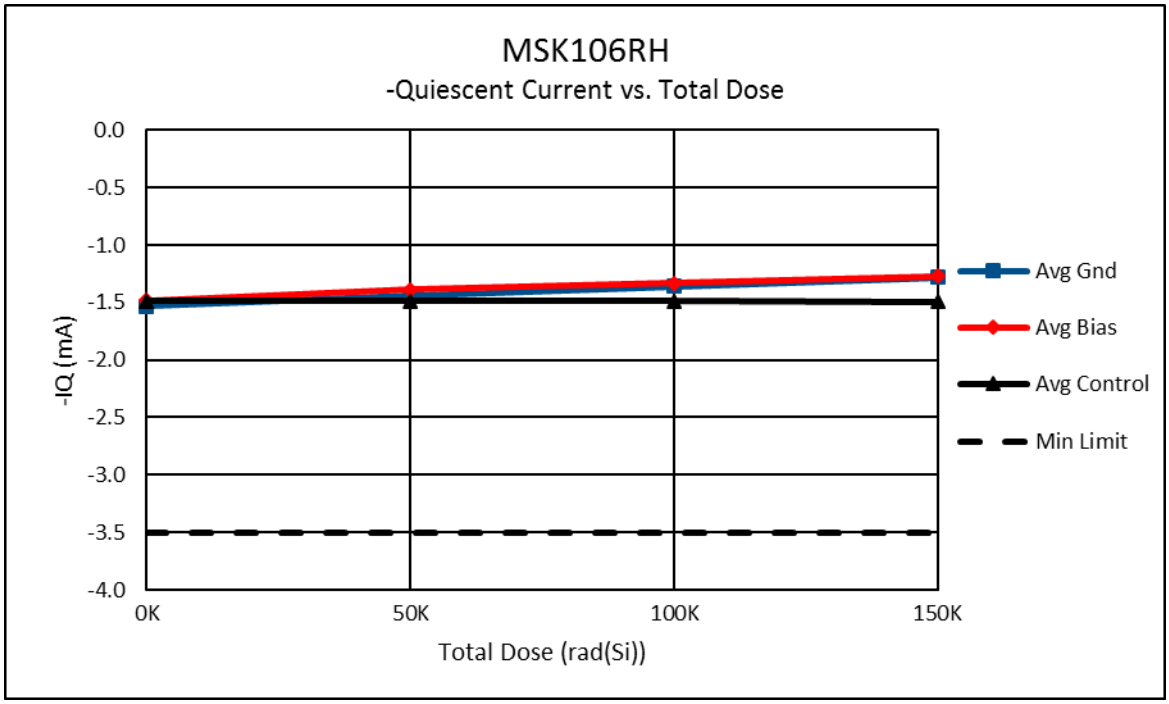
Biased S/N – 0015, 0016, 0017, 0018, 0019

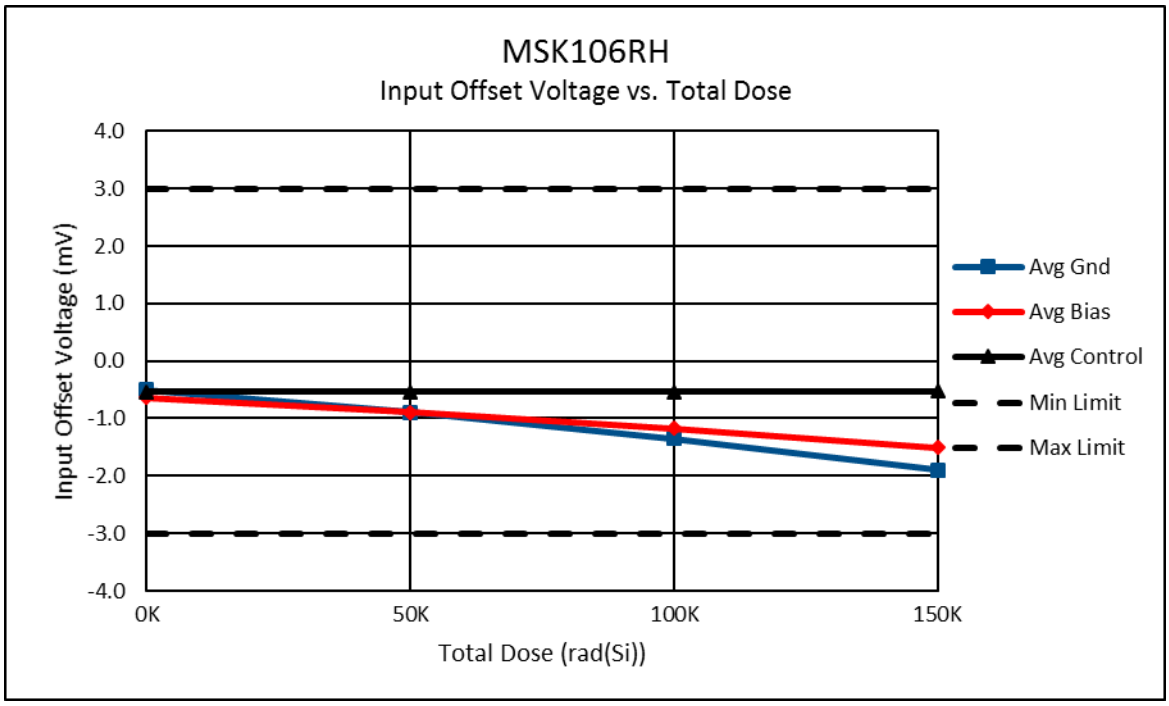
Unbiased S/N – 0020, 0021, 0022, 0023, 0024

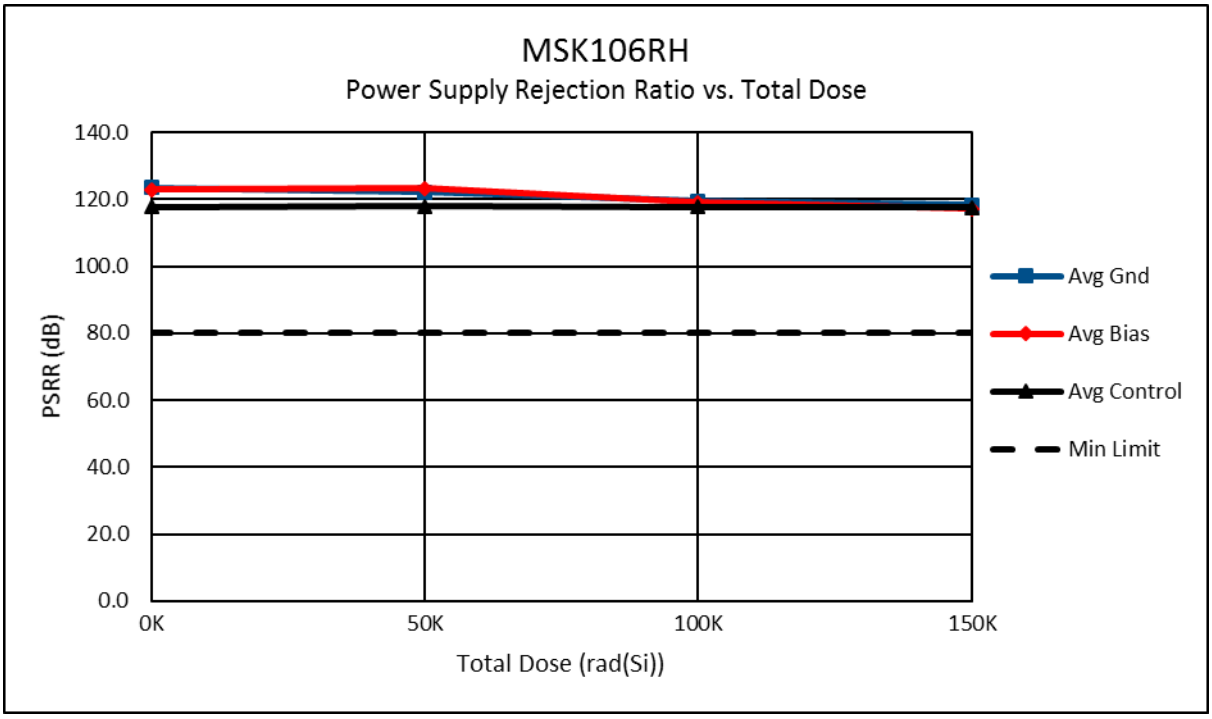
Table 1

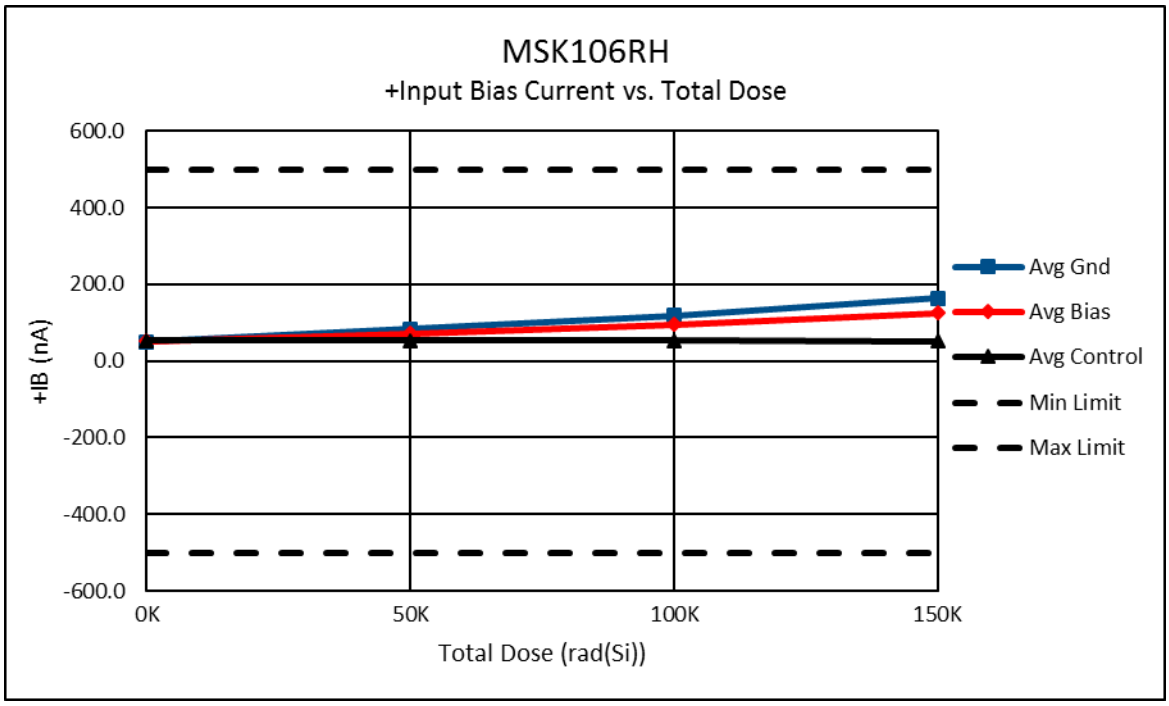
Dose Time, Incremental Dose and Total Cumulative Dose

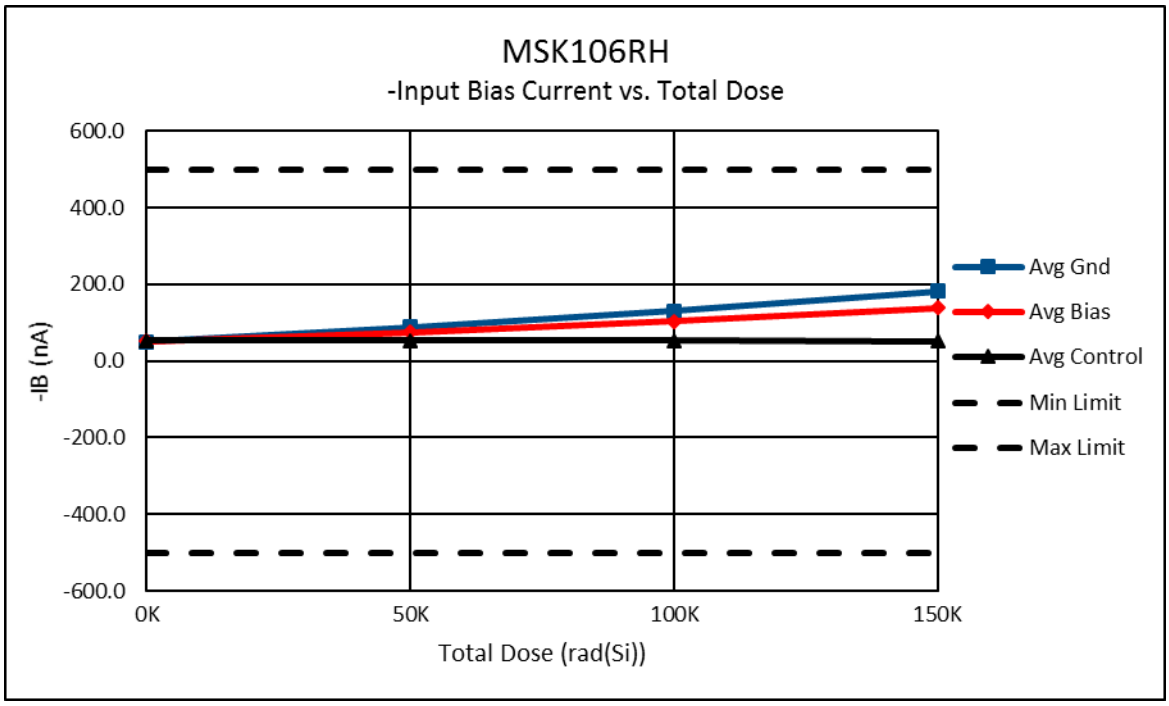

MSK106RH
+Quiescent Current vs. Total Dose
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
+IQ (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

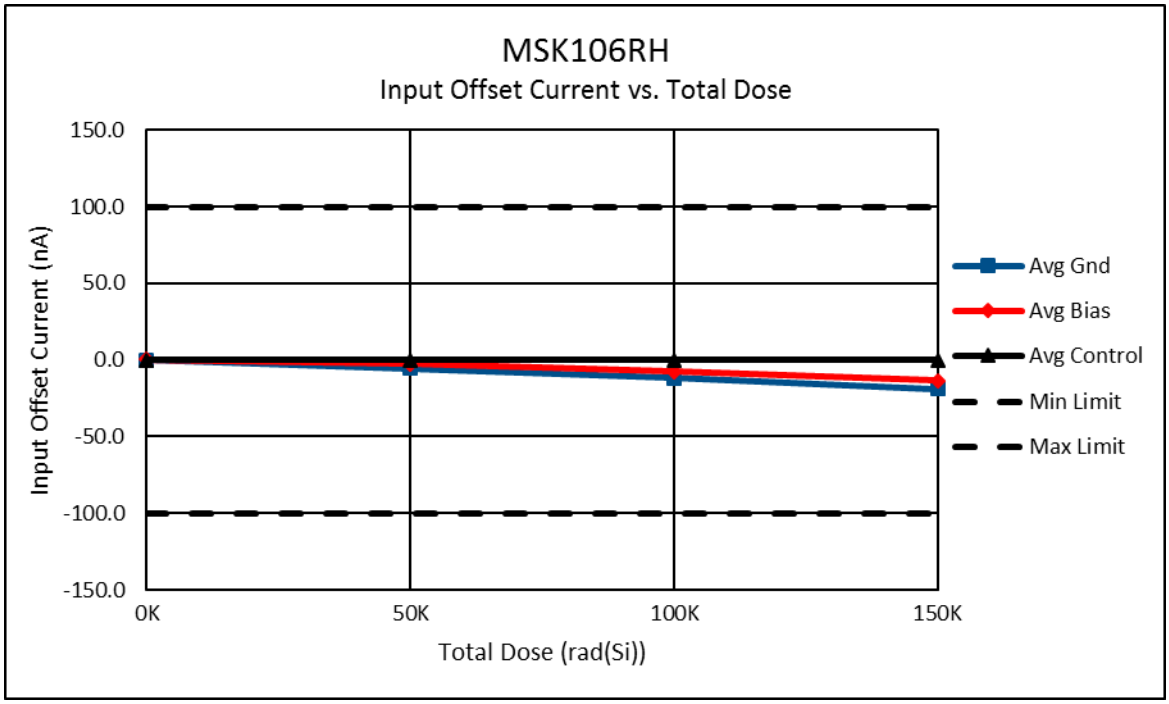

MSK106RH
-Quiescent Current vs. Total Dose
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-IQ (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

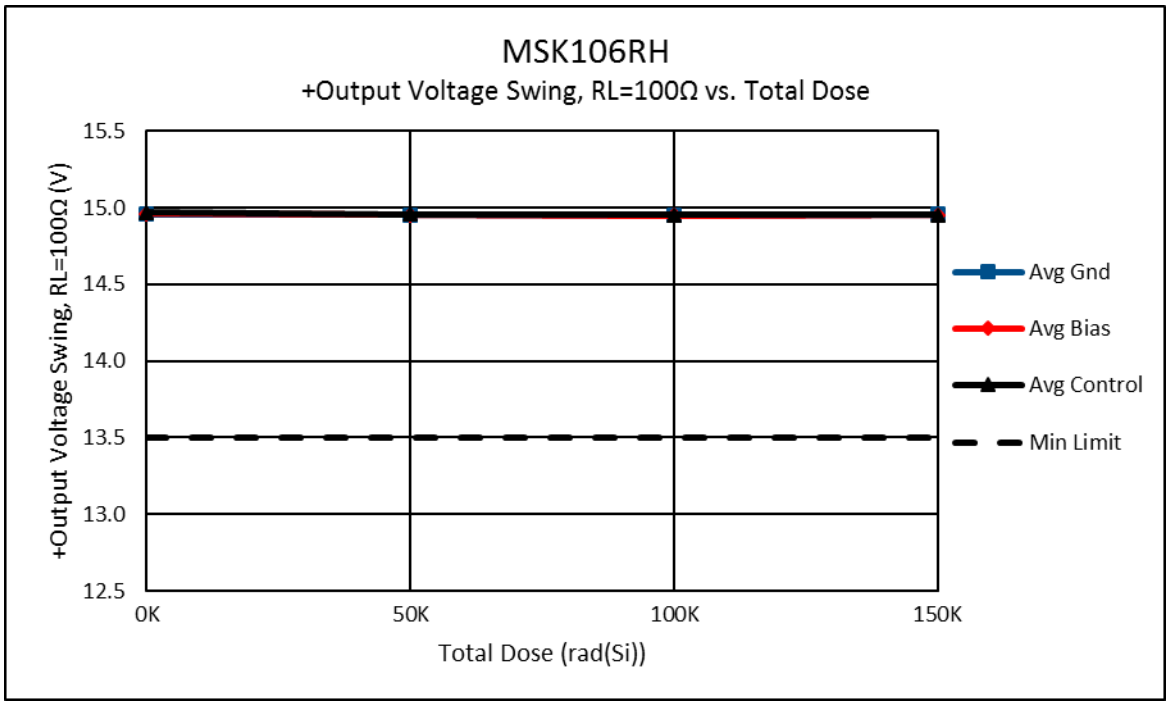

MSK106RH
Input Offset Voltage vs. Total Dose
Input Offset Voltage (mV)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

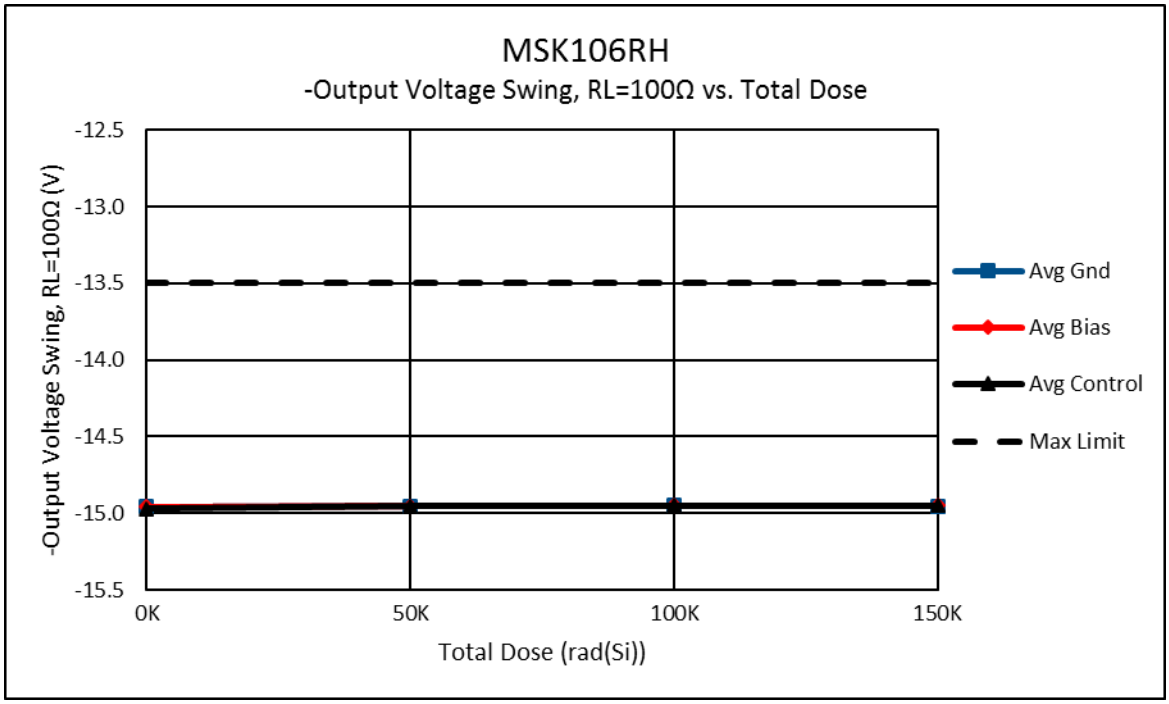

MSK106RH
Power Supply Rejection Ratio vs. Total Dose
PSRR (dB)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

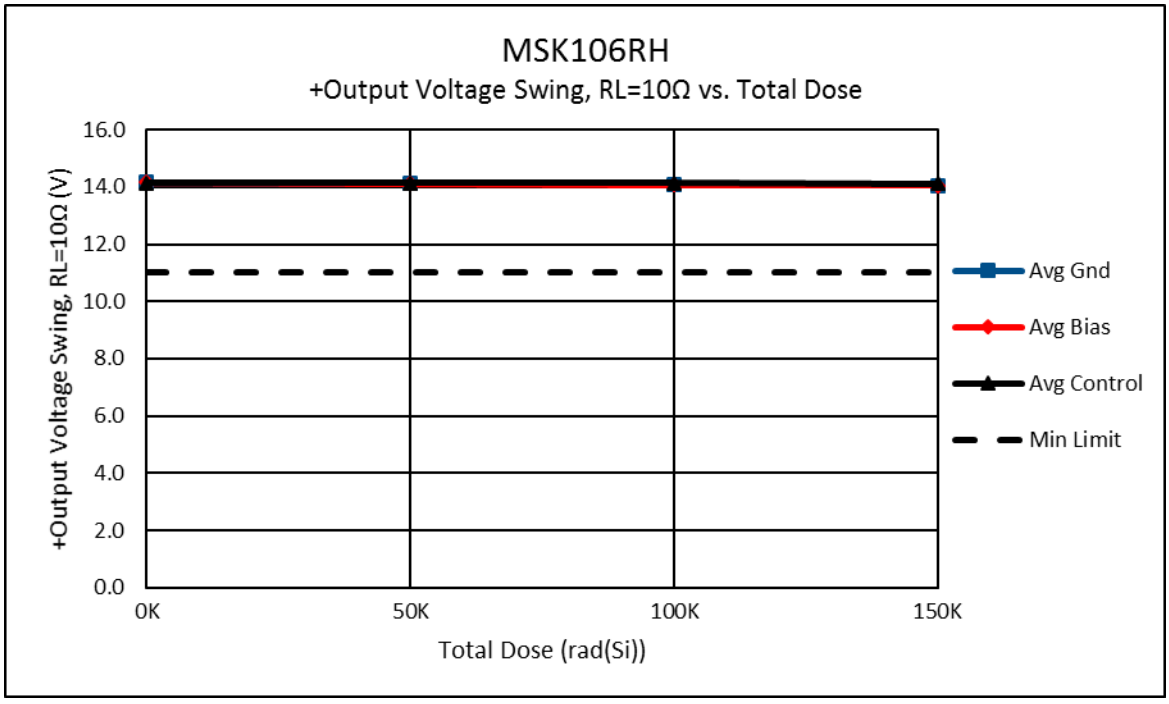

MSK106RH
+Input Bias Current vs. Total Dose
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
+IB (nA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

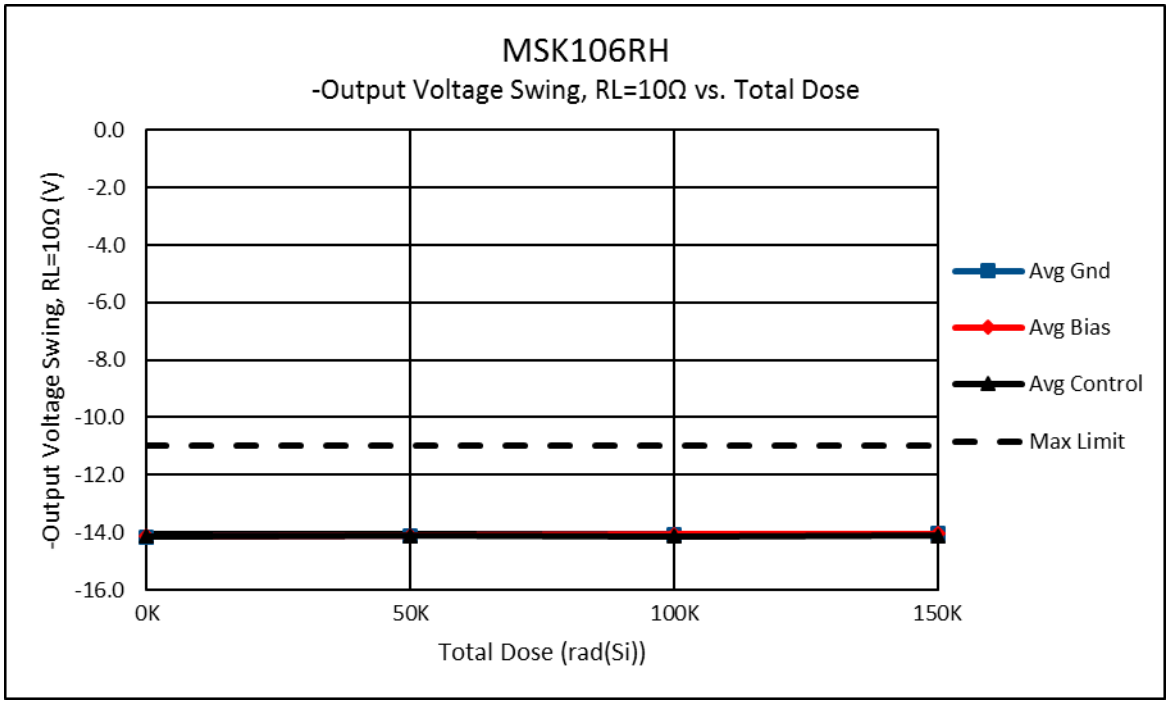

MSK106RH
-Input Bias Current vs. Total Dose
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
-IB (nA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

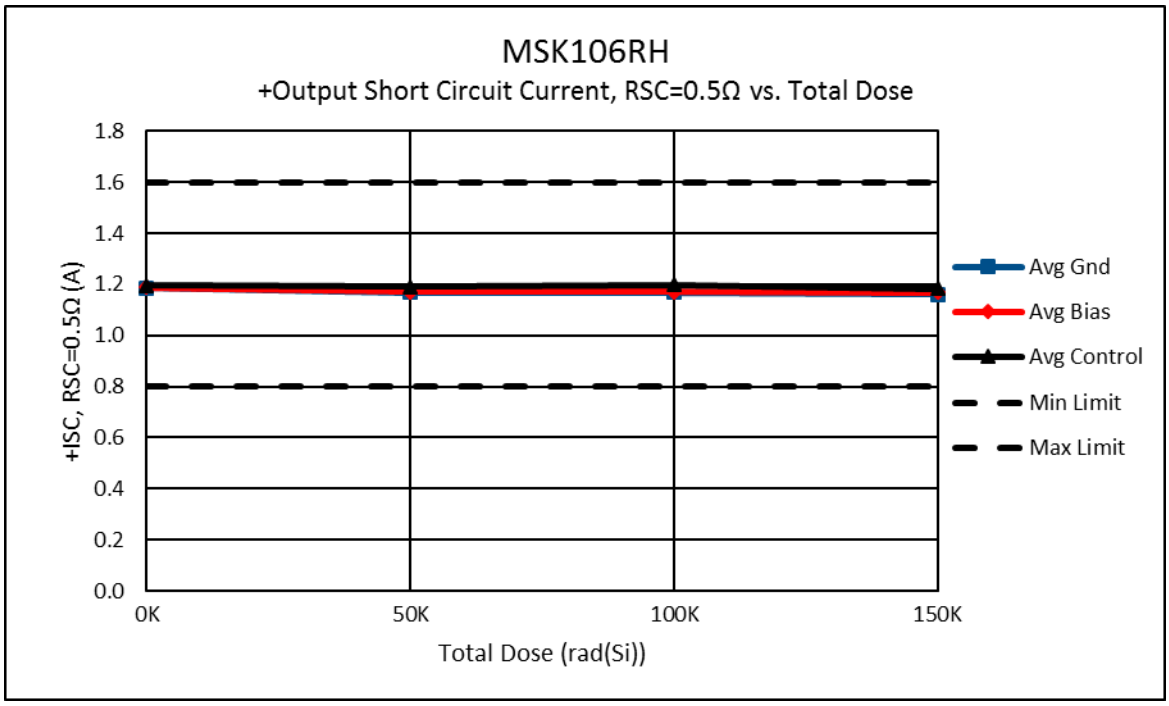

MSK106RH
Input Offset Current vs. Total Dose
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Input Offset Current (nA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

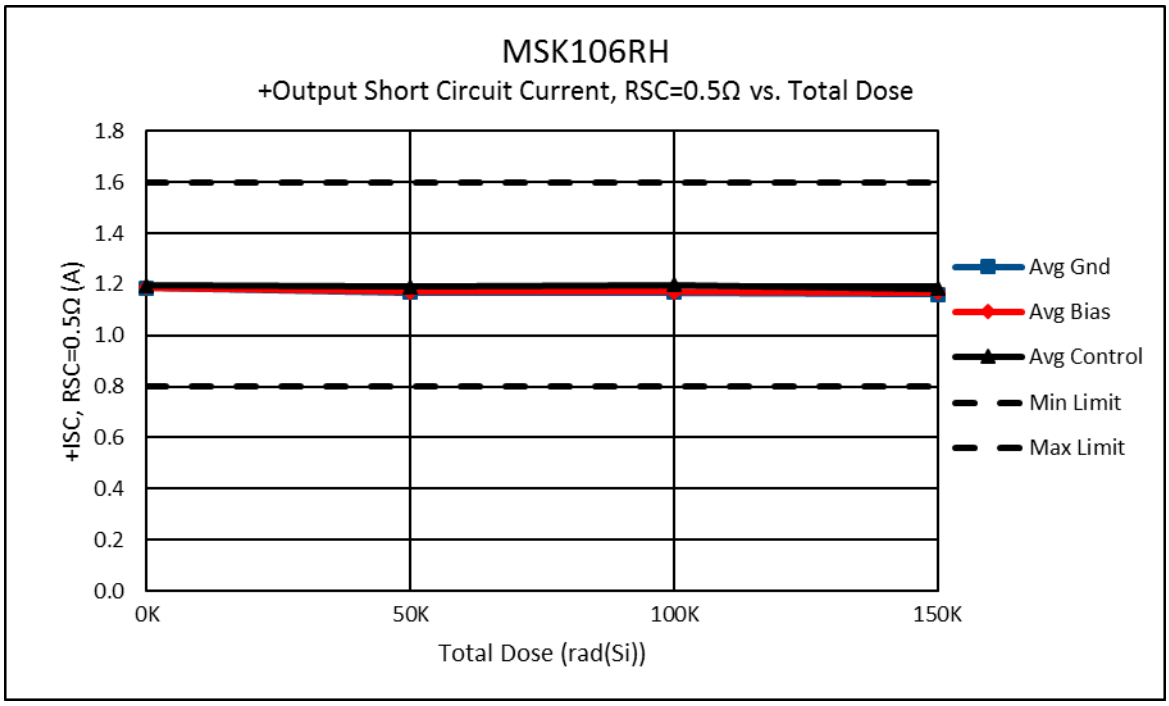

MSK106RH
+Output Voltage Swing, RL=100Ω vs. Total Dose
15.5
15.0
14.5
14.0
13.5
13.0
12.5
+Output Voltage Swing, RL=100Ω (V)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

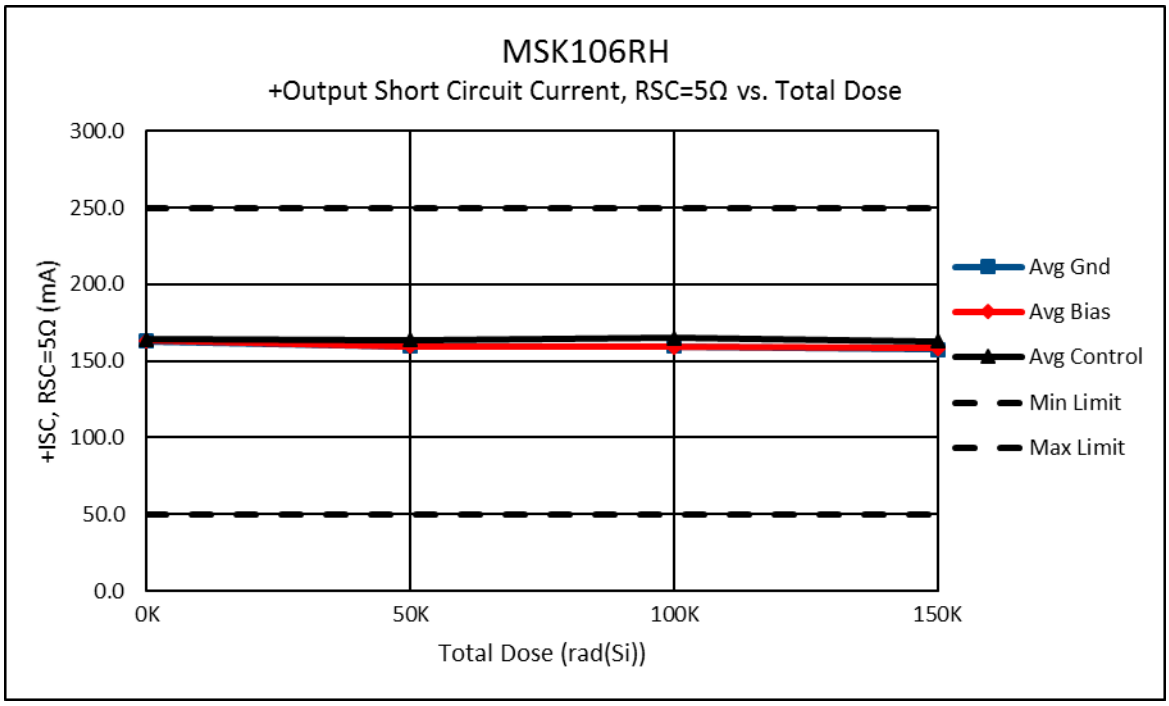

MSK106RH
-Output Voltage Swing, RL=100Ω vs. Total Dose
-Output Voltage Swing, RL=100Ω (V)
-12.5
-13.0
-13.5
-14.0
-14.5
-15.0
-15.5
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

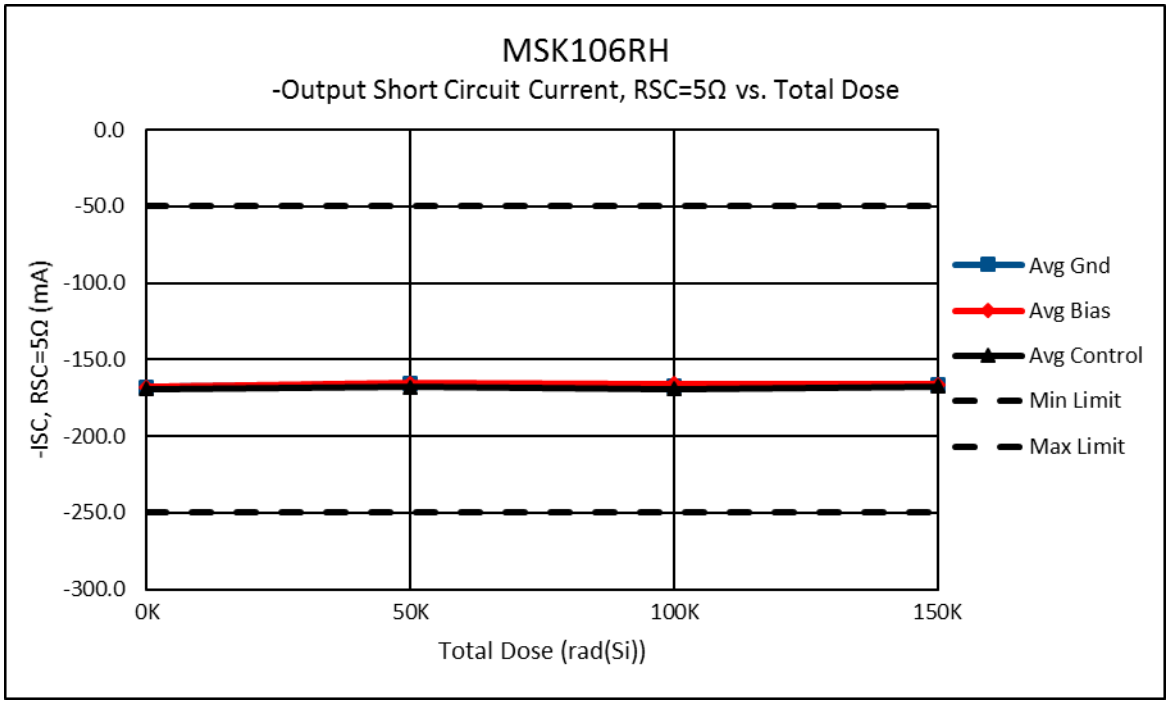

MSK106RH
+Output Voltage Swing, RL=10Ω vs. Total Dose
+Output Voltage Swing, RL=10Ω (V)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

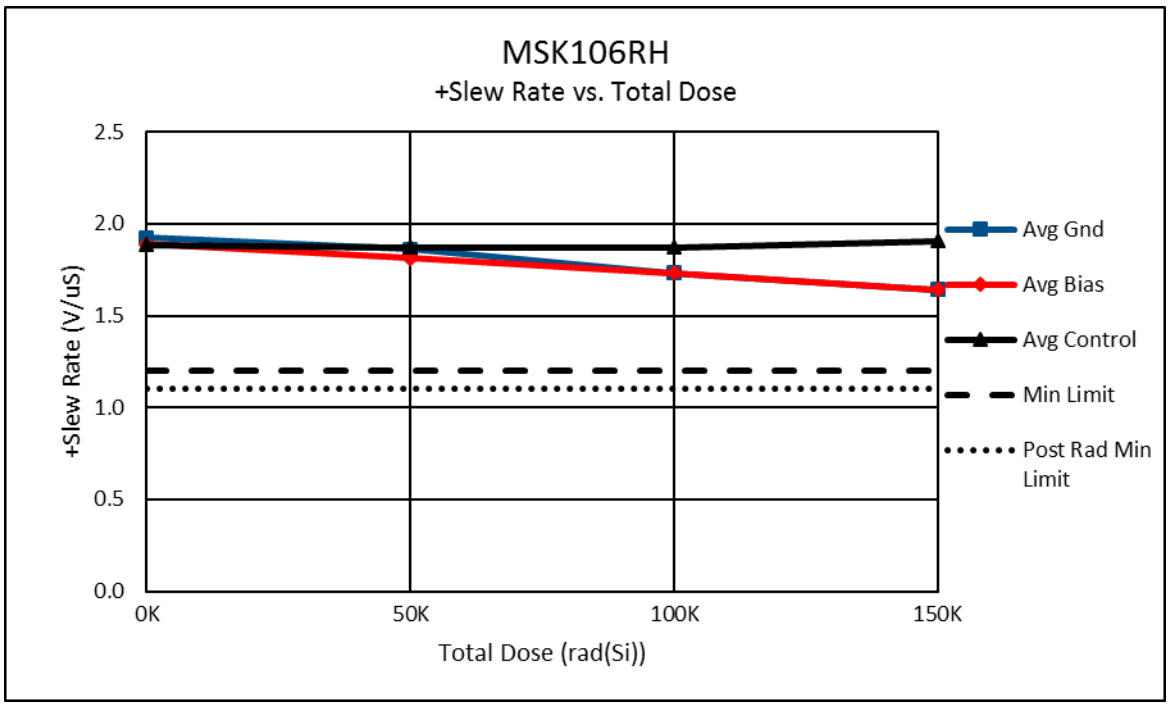

MSK106RH
-Output Voltage Swing, RL=10Ω vs. Total Dose
-Output Voltage Swing, RL=10Ω (V)
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

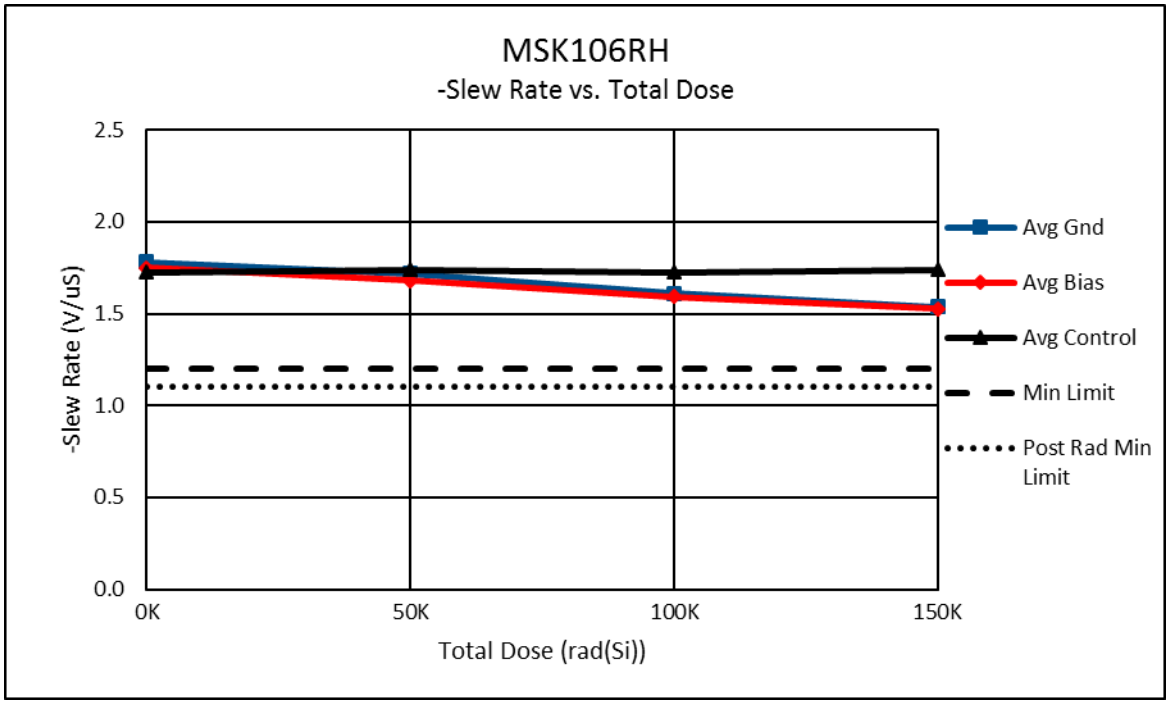

MSK106RH
+Output Short Circuit Current, RSC=0.5Ω vs. Total Dose
+ISC, RSC=0.5Ω (A)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

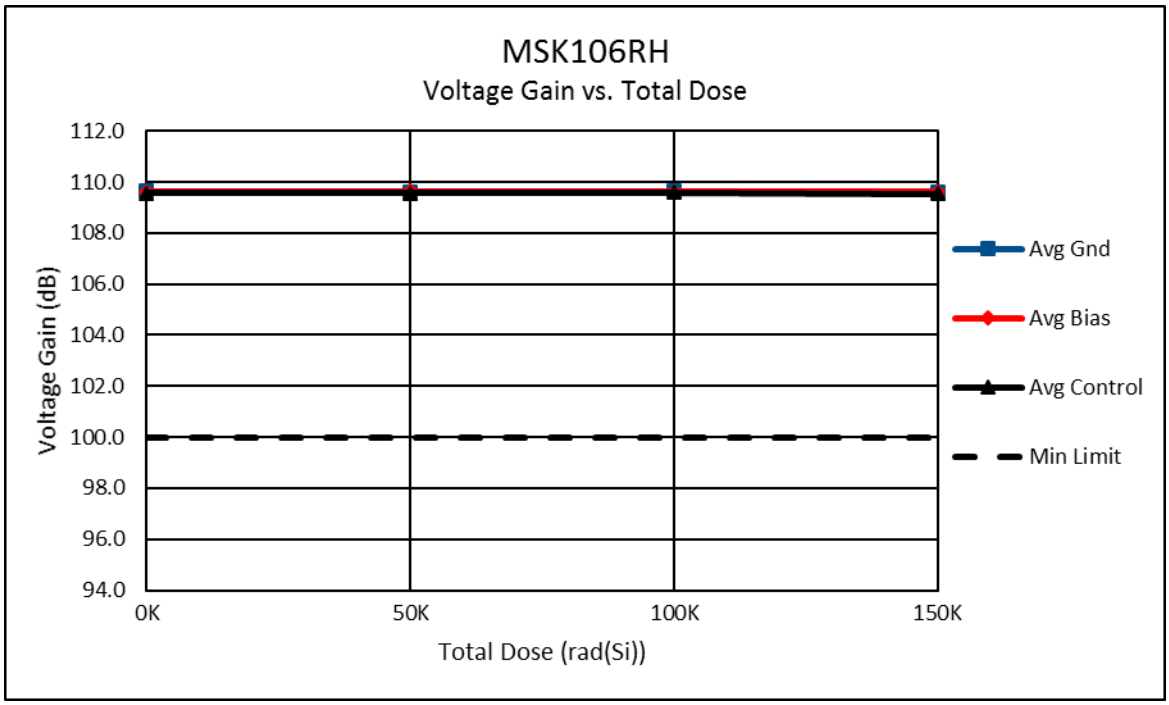

MSK106RH
+Output Short Circuit Current, RSC=0.5Ω vs. Total Dose
+ISC, RSC=0.5Ω (A)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

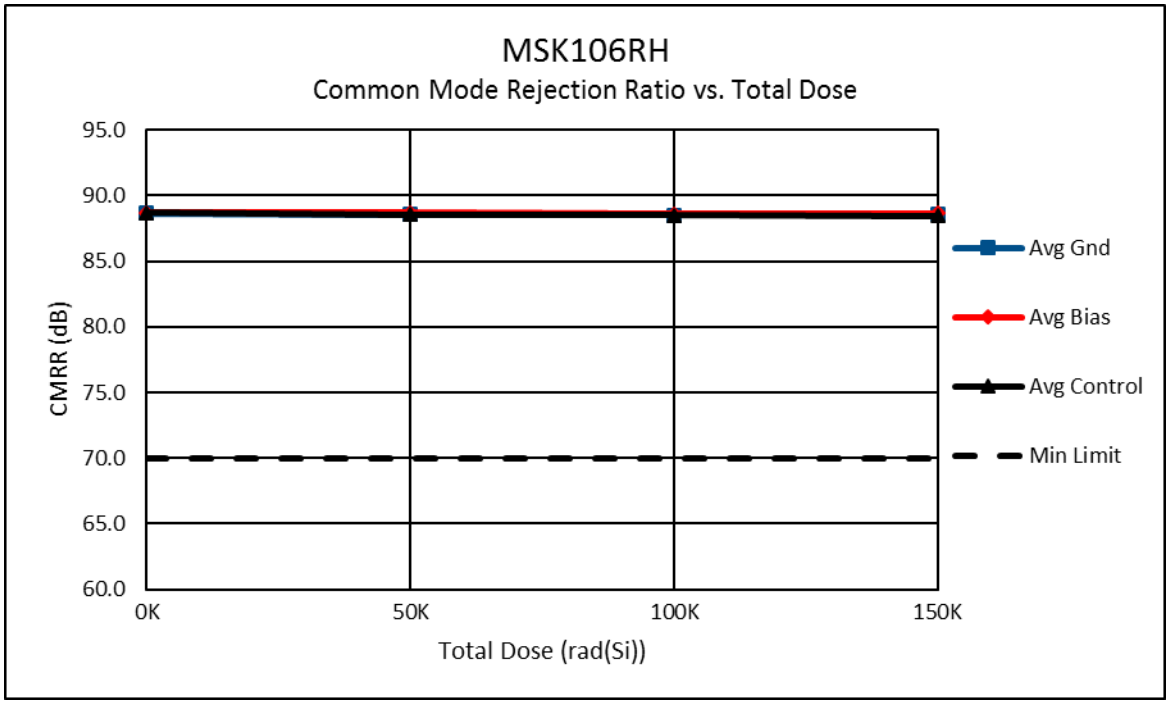

MSK106RH
+Output Short Circuit Current, RSC=5Ω vs. Total Dose
+ISC, RSC=5Ω (mA)
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

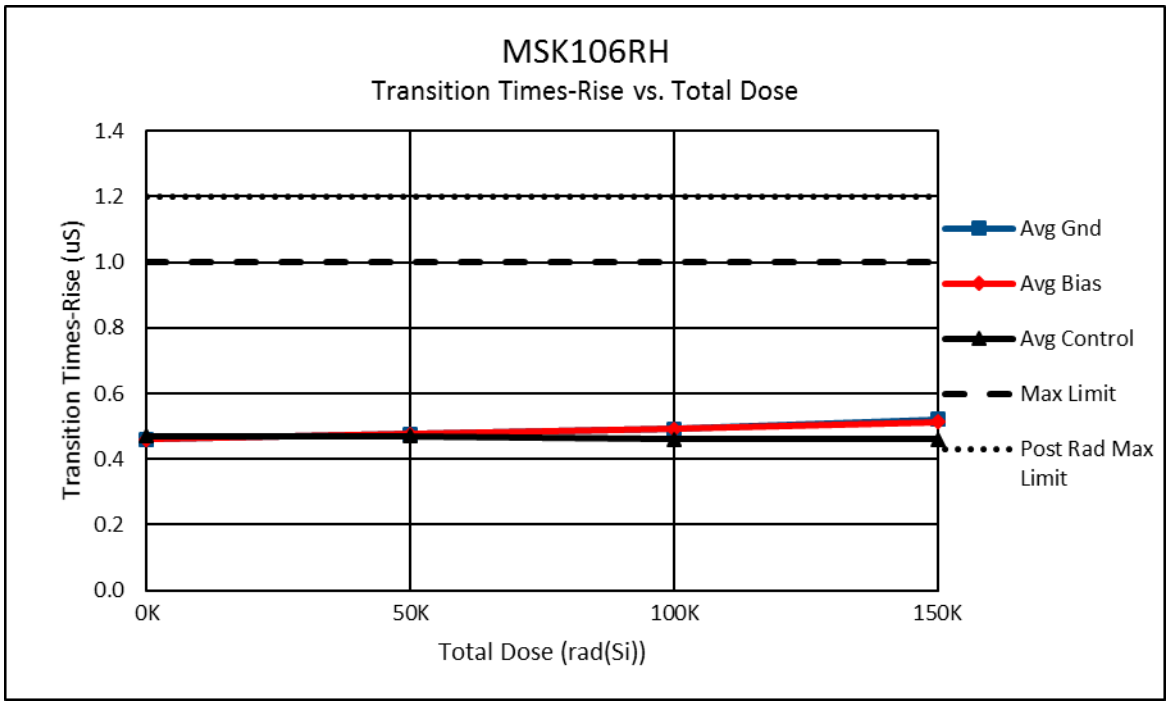

MSK106RH
-Output Short Circuit Current, RSC=5Ω vs. Total Dose
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
-300.0
-ISC, RSC=5Ω (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

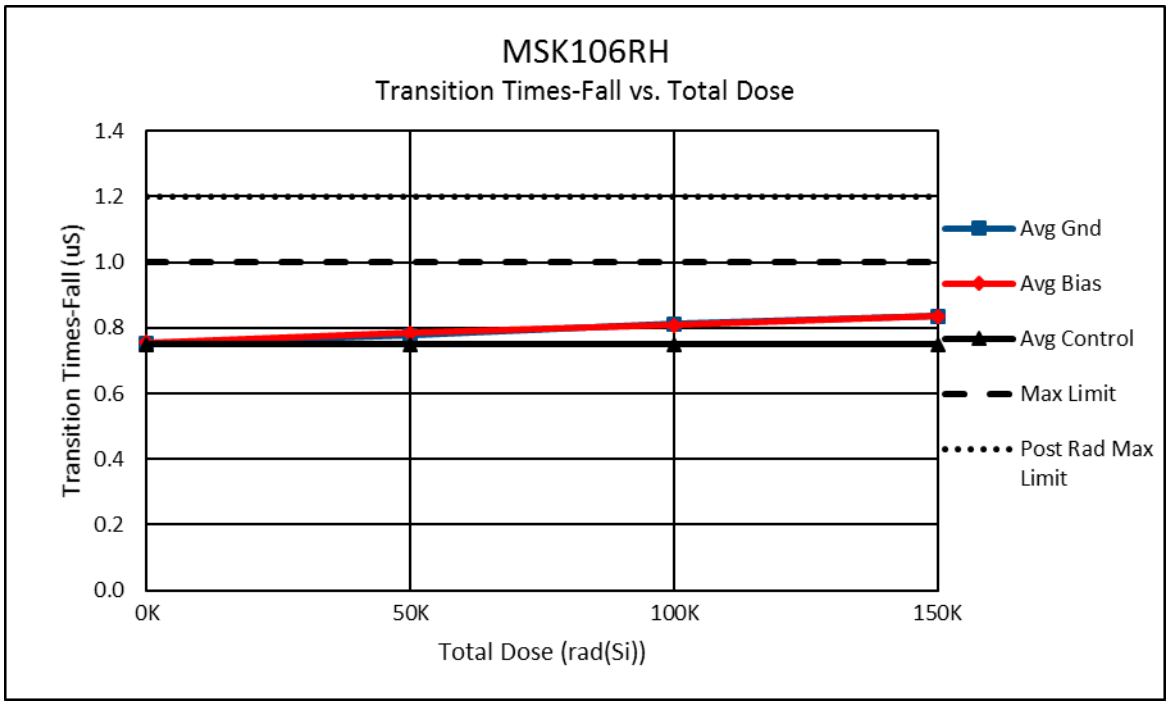

MSK106RH
+Slew Rate vs. Total Dose
2.5
2.0
1.5
1.0
0.5
0.0
+Slew Rate (V/uS)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Post Rad Min Limit

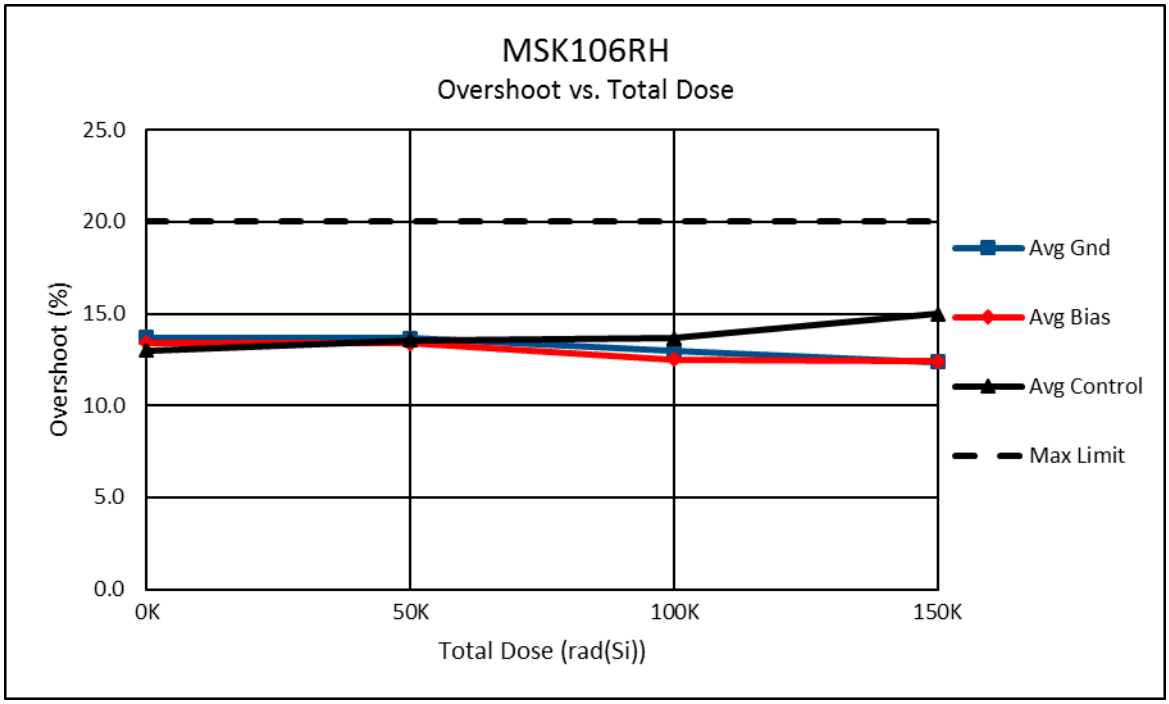

MSK106RH
-Slew Rate vs. Total Dose
2.5
2.0
1.5
1.0
0.5
0.0
-Slew Rate (V/uS)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Post Rad Min Limit


MSK106RH
Voltage Gain vs. Total Dose
112.0
110.0
108.0
106.0
104.0
102.0
100.0
98.0
96.0
94.0
Voltage Gain (dB)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit


MSK106RH
Common Mode Rejection Ratio vs. Total Dose
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
CMRR (dB)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit


MSK106RH
Transition Times-Rise vs. Total Dose
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Transition Times-Rise (uS)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit
Post Rad Max Limit


MSK106RH
Transition Times-Fall vs. Total Dose
Transition Times-Fall (uS)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit
Post Rad Max Limit


MSK106RH
Overshoot vs. Total Dose
Overshoot (%)
25.0
20.0
15.0
10.0
5.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

Total Dose Radiation Test Report

MSK106RH

Radiation Hardened High Power Op Amp

January 3, 2005 – TID (First Test)
Updated on August 4, 2006
Updated on January 25, 2008 (Second Test)
March 18, 2010 TID (Third Test)
April 24, 2013 – TID (Fourth Test)
September 15, 2017 – TID (Fifth Test)

N. Kresse
C. Salce
A. Olesh

Anaren, Inc. – MSK Products

I. Introduction:

The total dose radiation test plan for the MSK106RH was developed to qualify the device as radiation hardened up to 100 Krads(Si). The testing was performed beyond 100 Krads(Si) to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the hybrid, but simply offers designers insight to the critical parameter-shifts beyond the specified total dose level.

MIL-STD-883 Method 1019.7 and ASTM F1892-06 were used as guidelines in the development and implementation of the total dose test plan for the MSK106RH.

II. Radiation Source:

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. Dosimetry was performed prior to device irradiation and the dose rate was determined to be 141 rads(Si)/sec. The total dose schedule can be found in Table I.

III. Test Setup:

All test samples were subjected to Group A Electrical Test in accordance with the device data sheet. In addition, all devices received 160 hours of burn-in per MIL-STD-883 Method 1015 and were electrically tested prior to irradiation. For test platform verification, two control devices were tested at 25°C.

The devices were vertically aligned with the radiation source and enclosed in a lead/aluminum container during irradiation. An operating voltage of +/-18 Volts was used for the bias condition. Four devices were kept under bias during irradiation. Four devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and were transported to the MSK automatic electrical test platform and tested IAW MSK device data sheet. Testing was performed on irradiated devices, as well as two control devices, at each total dose level. Electrical tests were completed within one hour of irradiation. Subsequent dosing was performed within two hours.

IV. Data:

All performance curves are averaged from the test results of the biased and unbiased devices respectively. If required, full test data can be obtained by contacting Anaren, Inc. - MSK Products.

V. Summary:

The devices performed well with respect to TID, qualifying to 100 Krads(Si) by the 99/90 statistical analysis of the test data.

Quiescent current decreased as testing progressed. Input bias current increased significantly as testing progressed. Both quiescent current and input bias current stayed within specification limits to 150 Krads(Si).

Positive and negative slew rate decreased, while Transition Times showed a slight increase as testing progressed, but stayed within pre-irradiation limits to 150 Krads(Si).

MSK106RH Biased/Unbiased Dose Rate Schedule

Dosimetry Equipment
Bruker Biospin # 0162

Irradiation Date
9/15/17

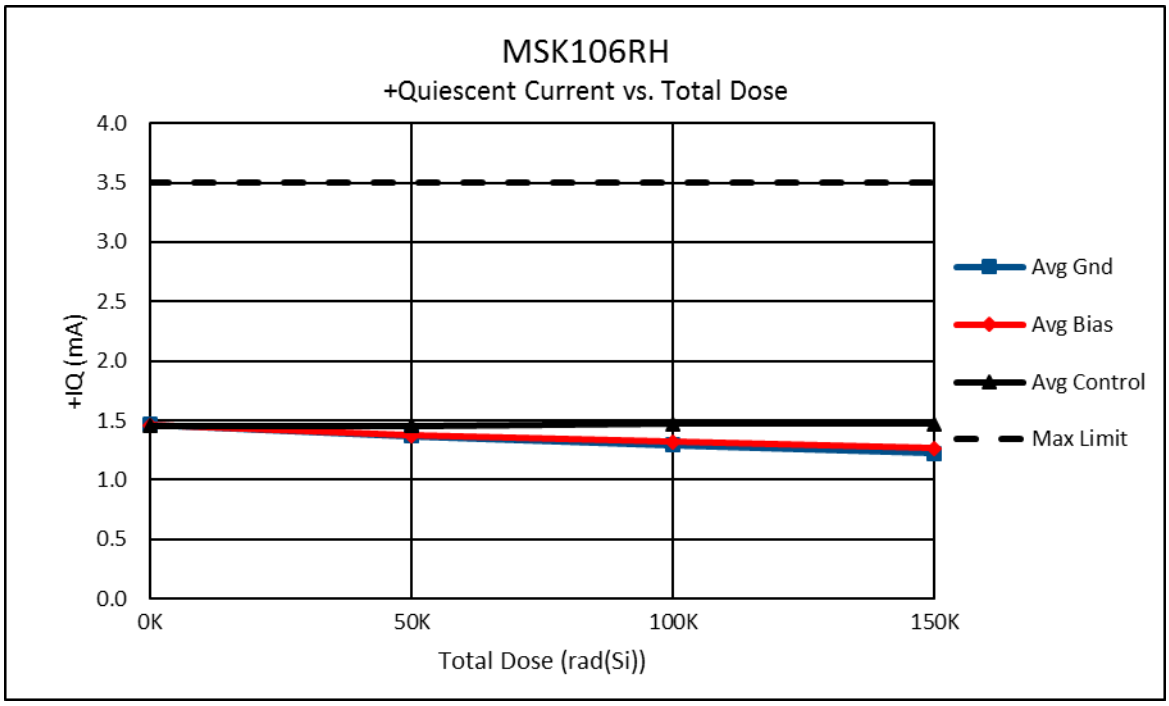
Exposure Length (min:sec)	Incremental Dose rads(Si)	Cumulative Dose rads(Si)
6:05	51,500	51,500
6:05	51,500	103,000
6:05	51,500	154,500

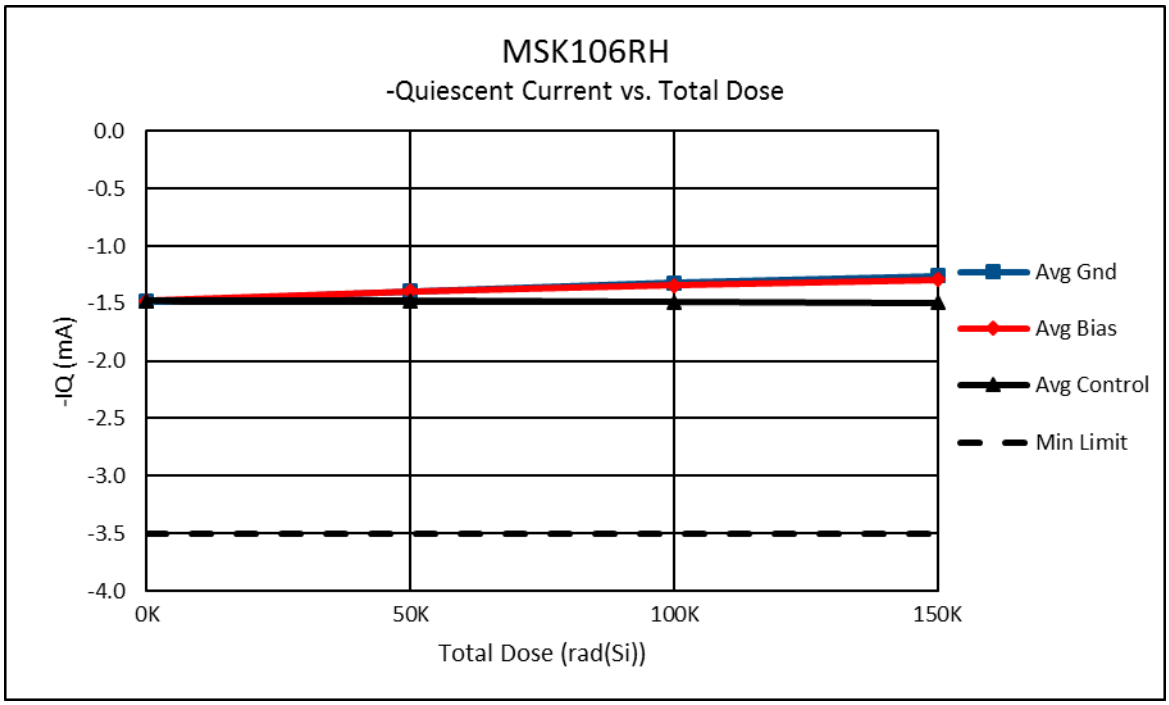
Biased S/N – 0604, 0605, 0607, 0608

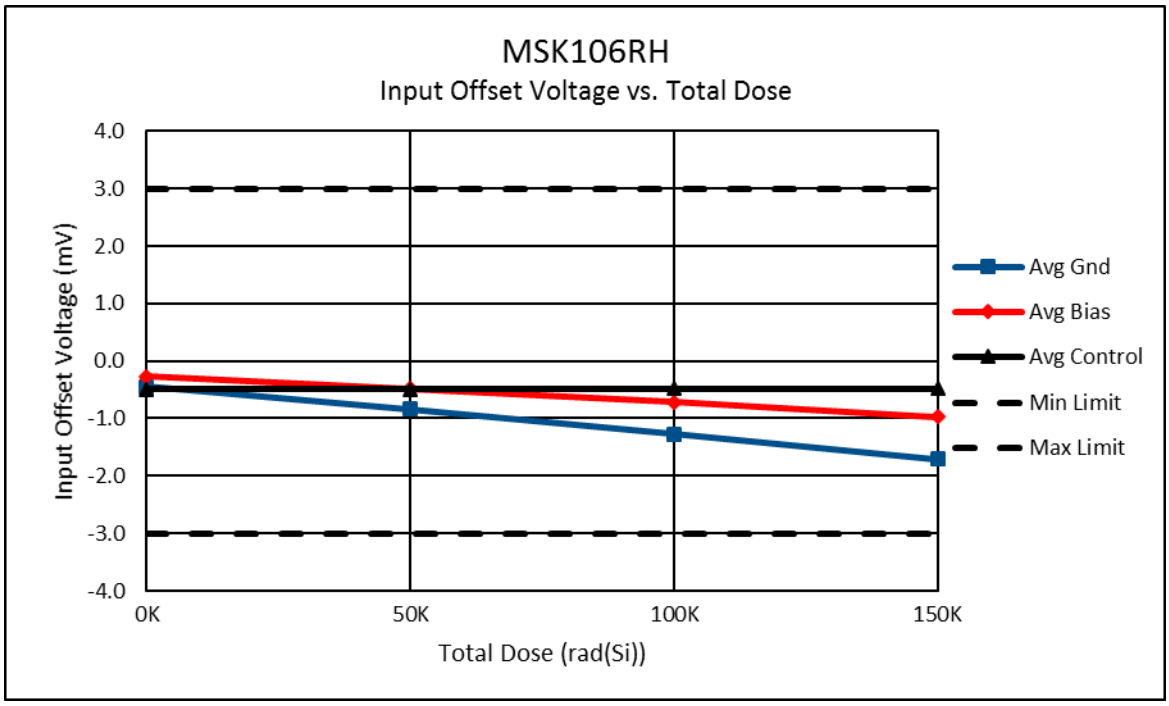
Unbiased S/N – 0609, 0610, 0611, 0613

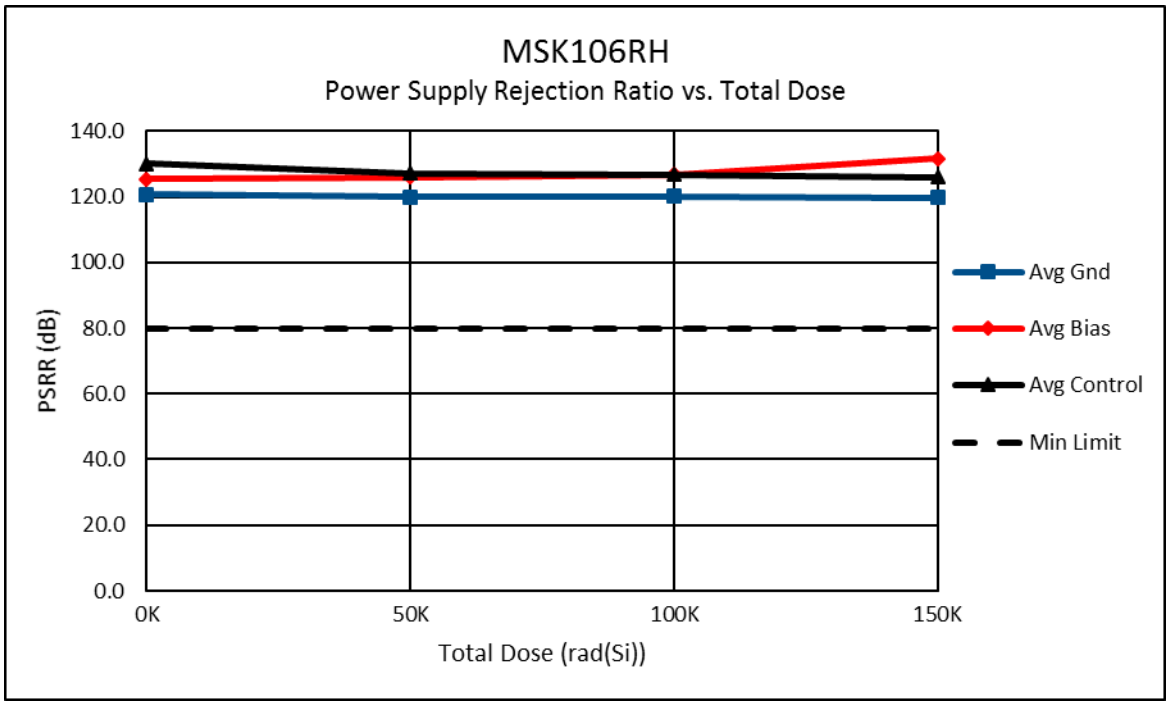
Table 1

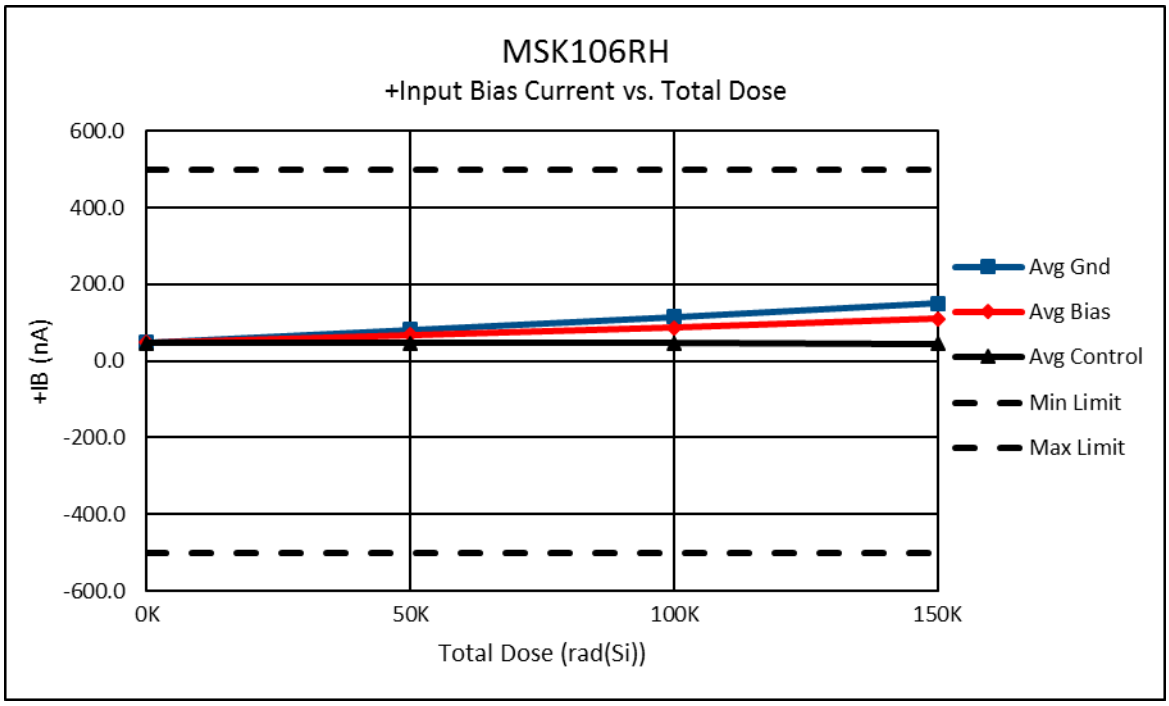
Dose Time, Incremental Dose and Total Cumulative Dose

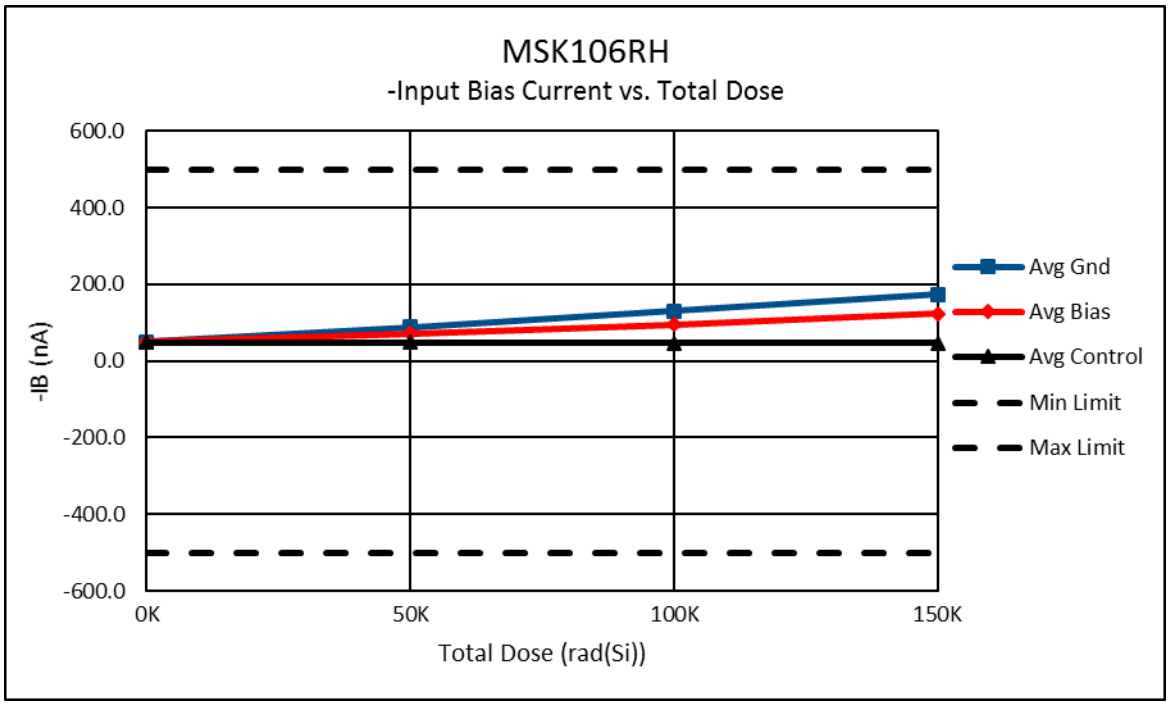

MSK106RH
+Quiescent Current vs. Total Dose
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
+IQ (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

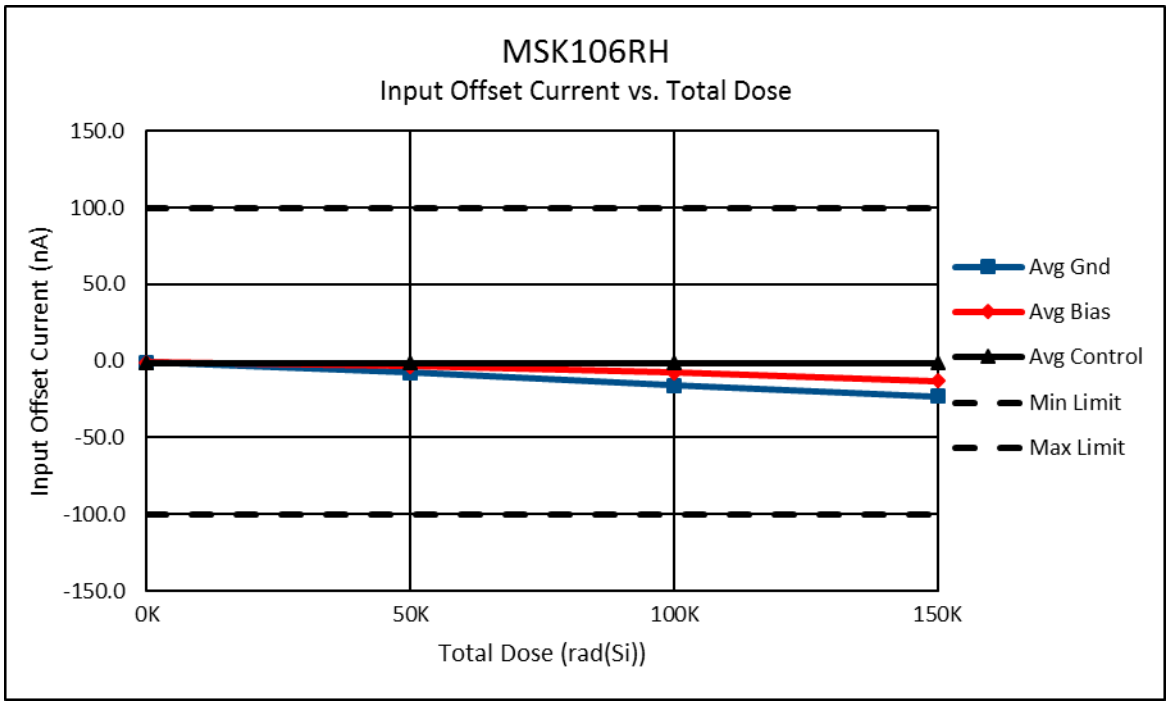

MSK106RH
-Quiescent Current vs. Total Dose
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
-IQ (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

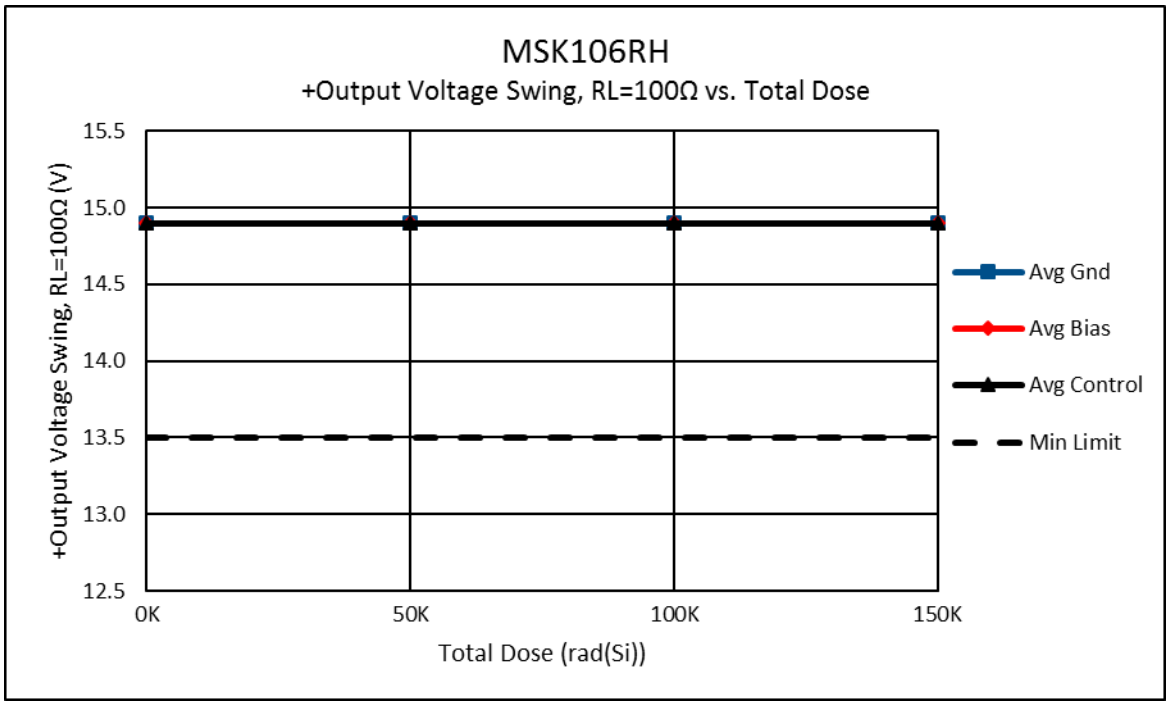

MSK106RH
Input Offset Voltage vs. Total Dose
Input Offset Voltage (mV)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

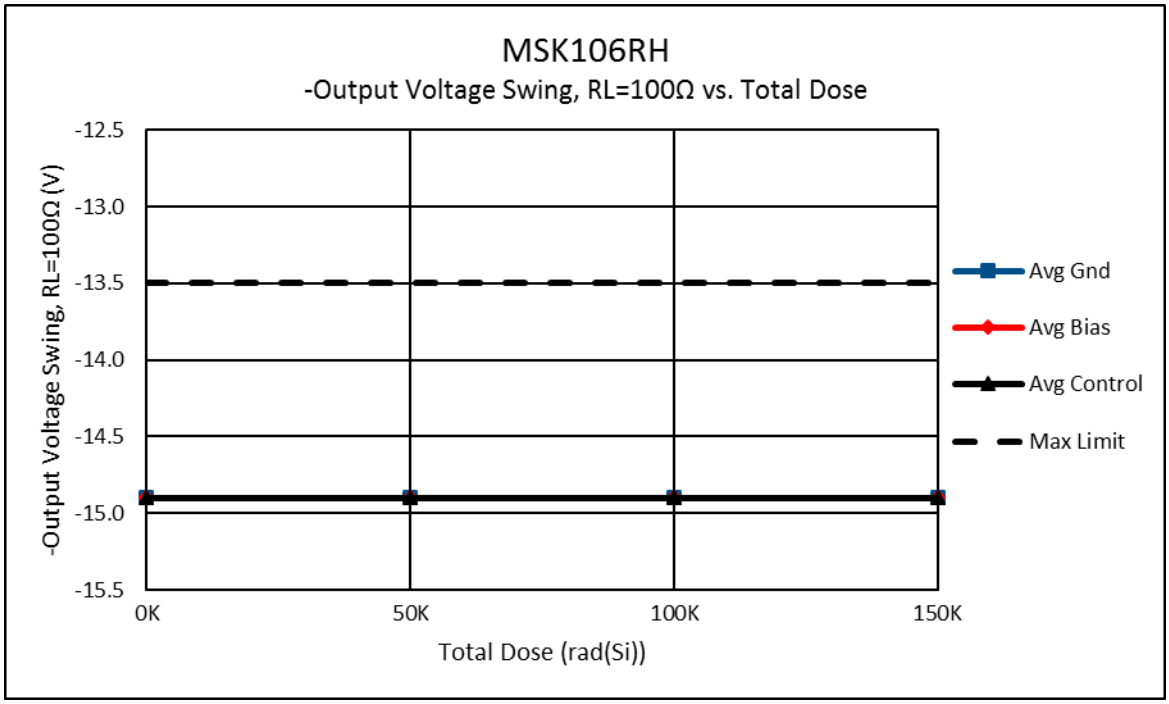

MSK106RH
Power Supply Rejection Ratio vs. Total Dose
PSRR (dB)
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

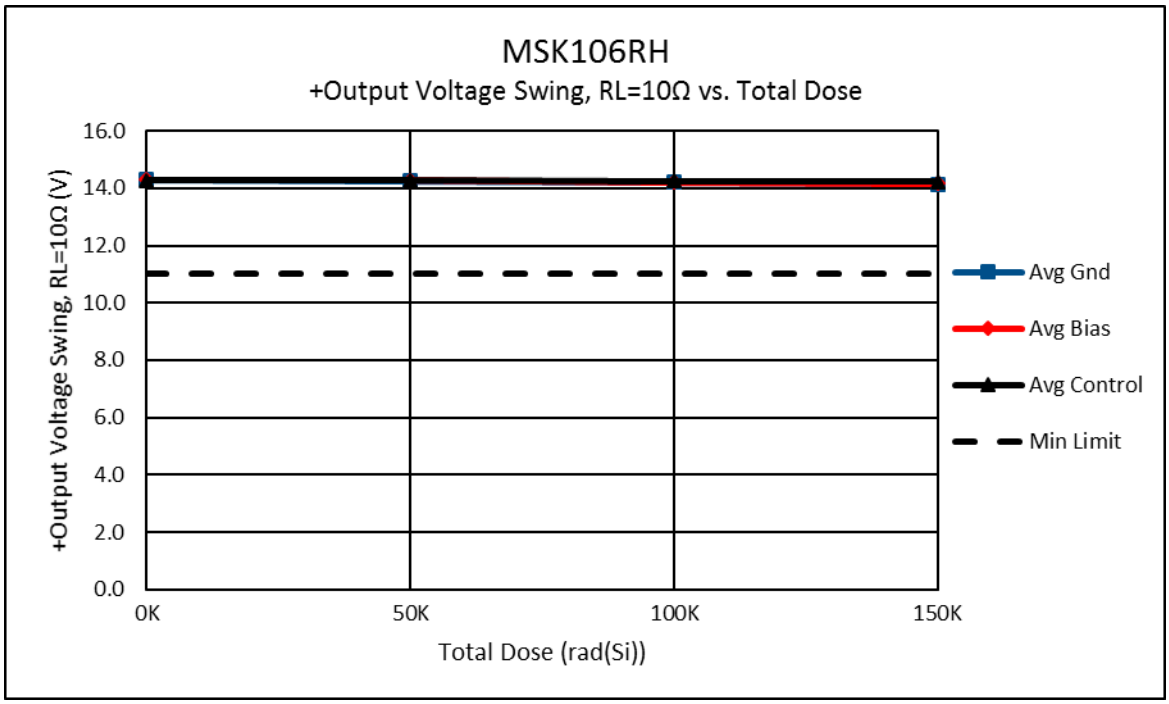

MSK106RH
+Input Bias Current vs. Total Dose
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
+IB (nA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

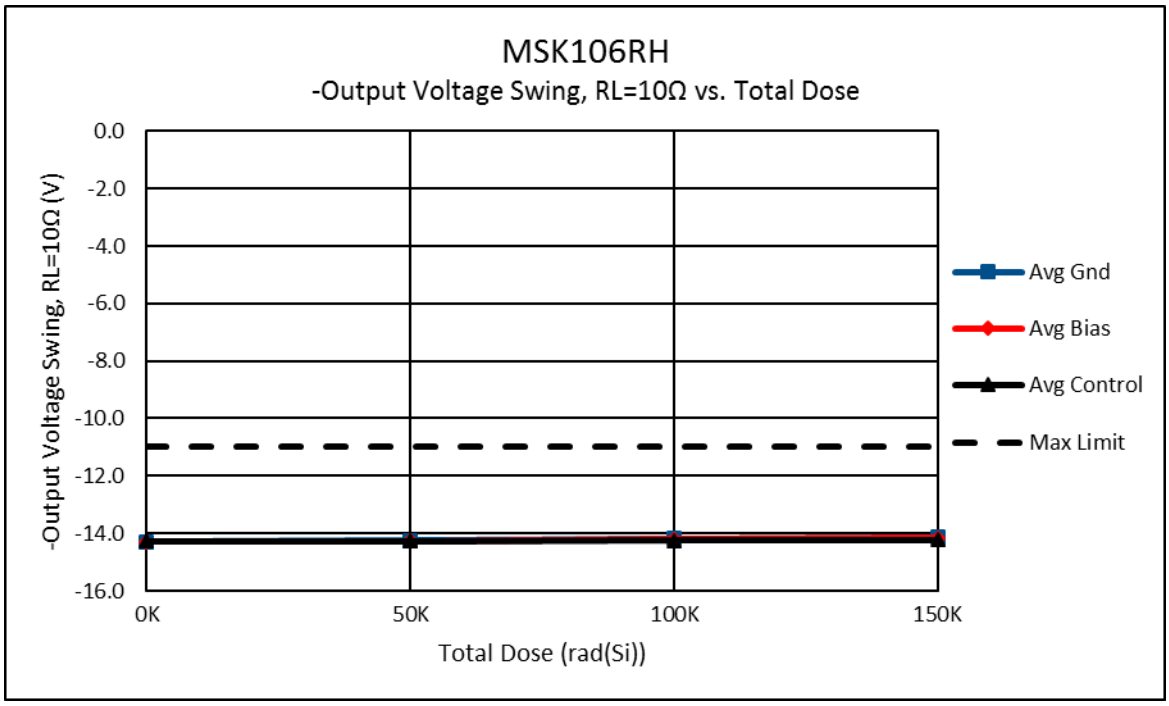

MSK106RH
-Input Bias Current vs. Total Dose
600.0
400.0
200.0
0.0
-200.0
-400.0
-600.0
-IB (nA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

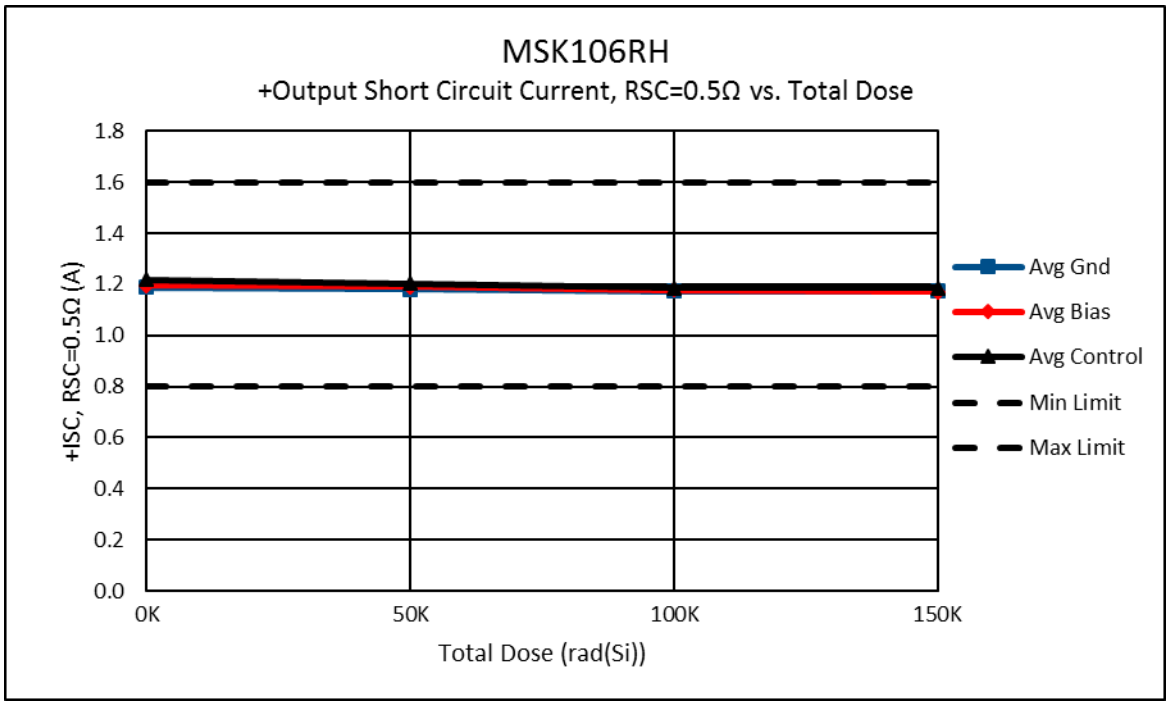

MSK106RH
Input Offset Current vs. Total Dose
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
Input Offset Current (nA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

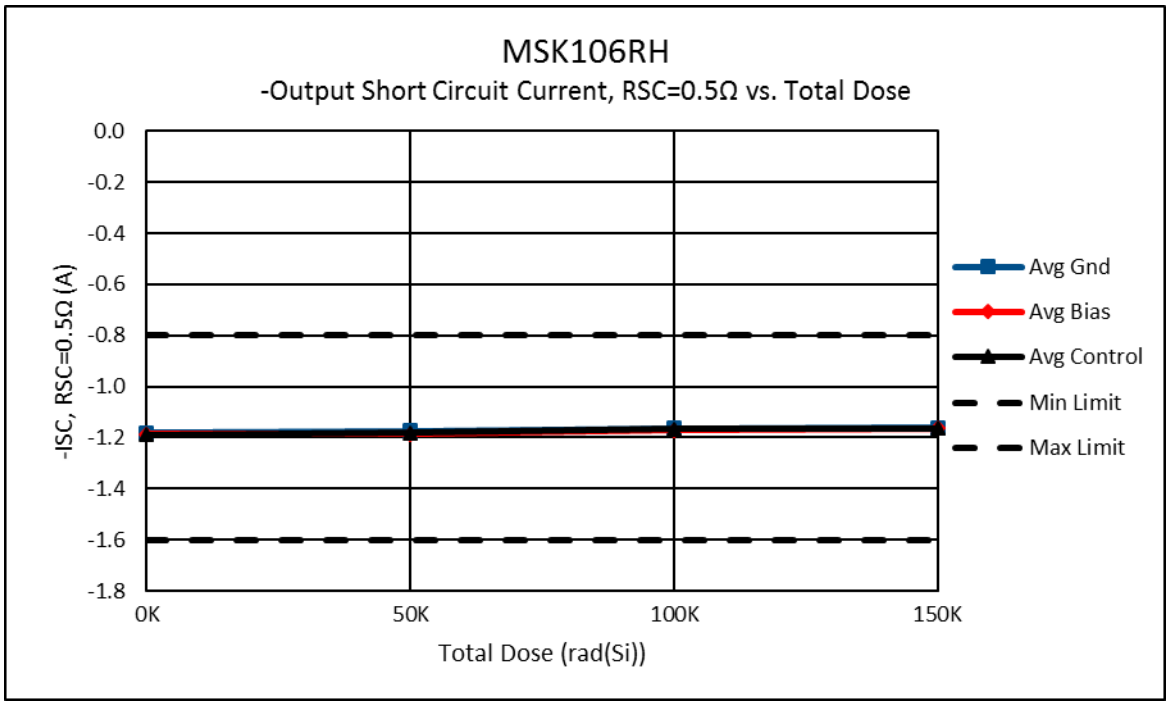

MSK106RH
+Output Voltage Swing, RL=100Ω vs. Total Dose
15.5
15.0
14.5
14.0
13.5
13.0
12.5
+Output Voltage Swing, RL=100Ω (V)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

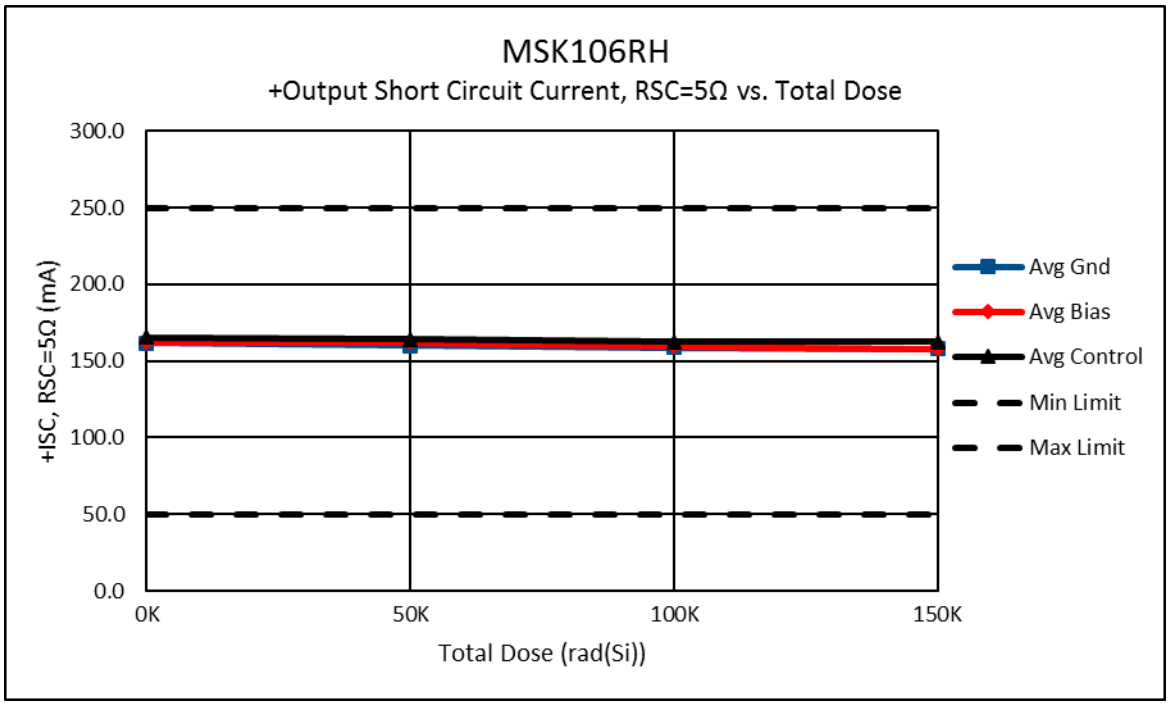

MSK106RH
-Output Voltage Swing, RL=100Ω vs. Total Dose
-Output Voltage Swing, RL=100Ω (V)
-12.5
-13.0
-13.5
-14.0
-14.5
-15.0
-15.5
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

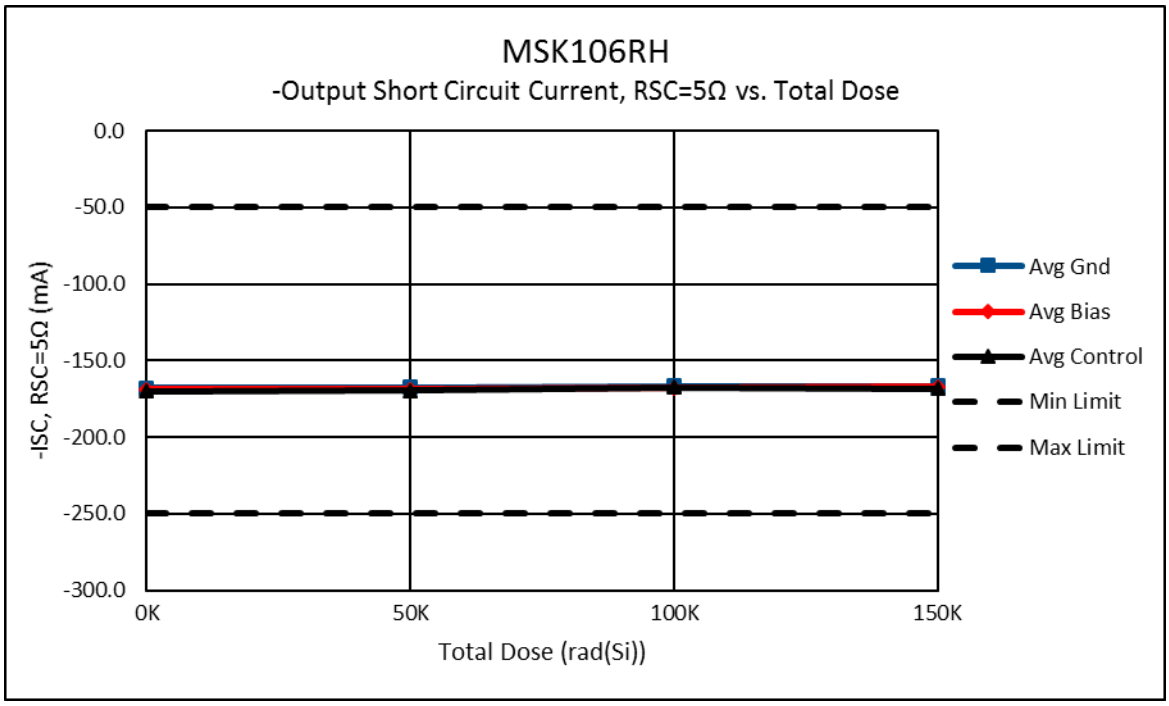

MSK106RH
+Output Voltage Swing, RL=10Ω vs. Total Dose
+Output Voltage Swing, RL=10Ω (V)
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit

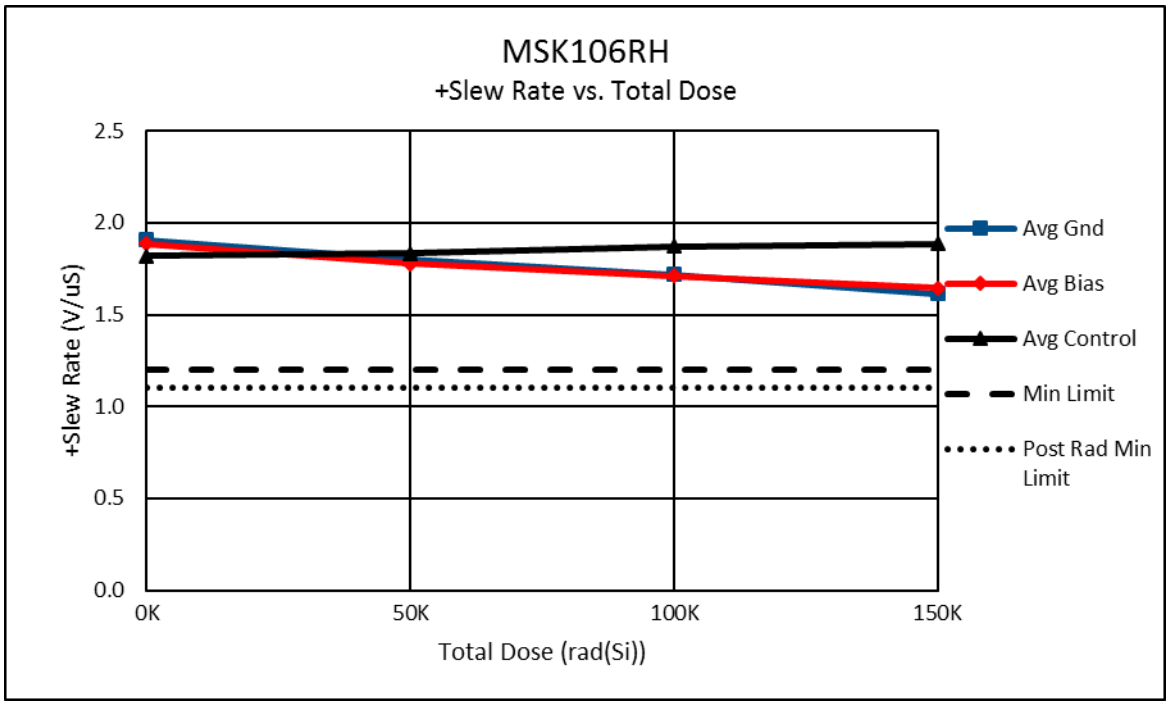

MSK106RH
-Output Voltage Swing, RL=10Ω vs. Total Dose
-Output Voltage Swing, RL=10Ω (V)
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

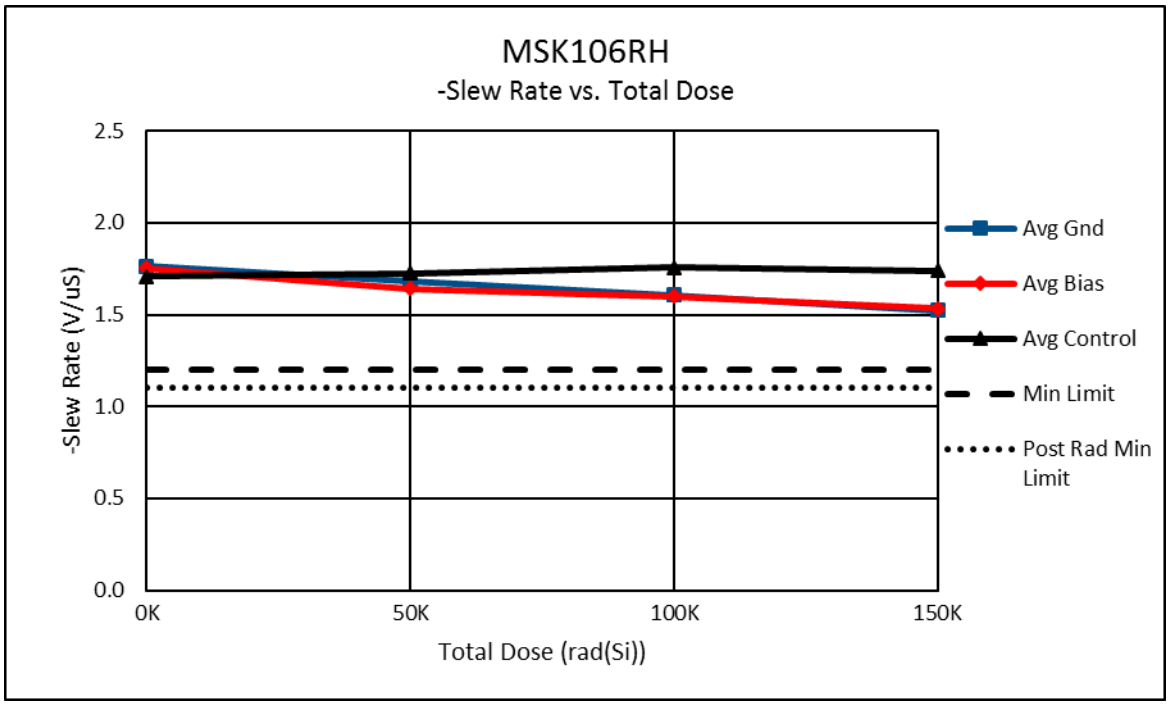

MSK106RH
+Output Short Circuit Current, RSC=0.5Ω vs. Total Dose
+ISC, RSC=0.5Ω (A)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

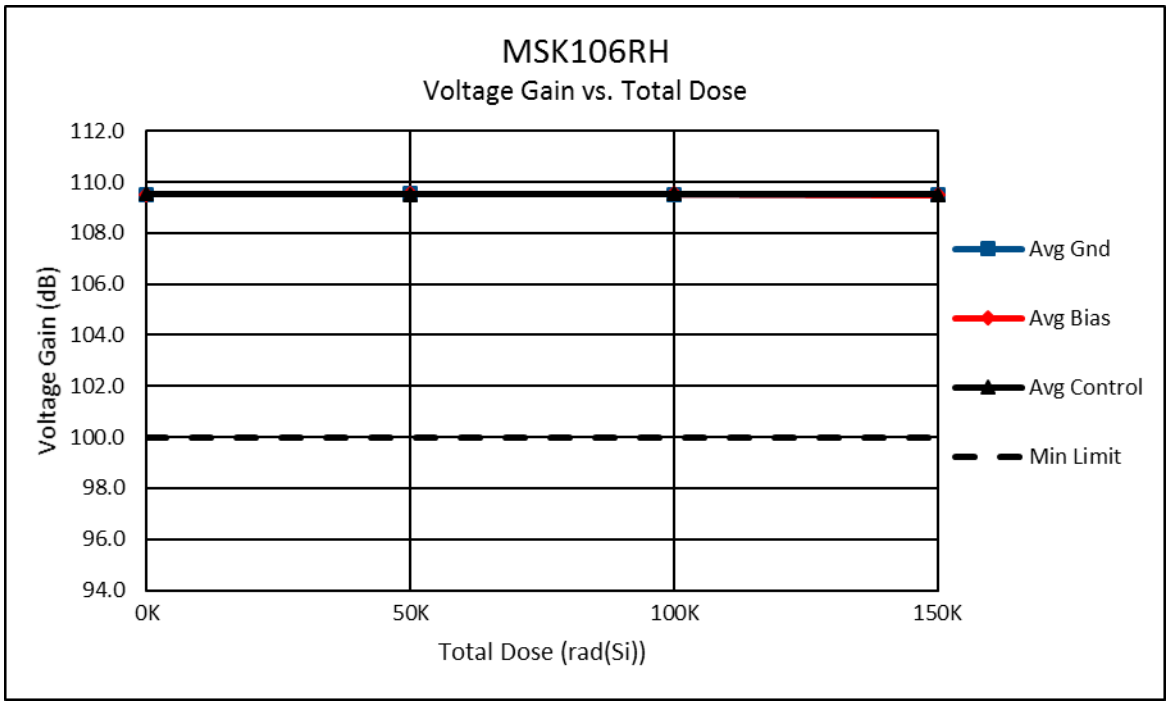

MSK106RH
-Output Short Circuit Current, RSC=0.5Ω vs. Total Dose
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-ISC, RSC=0.5Ω (A)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

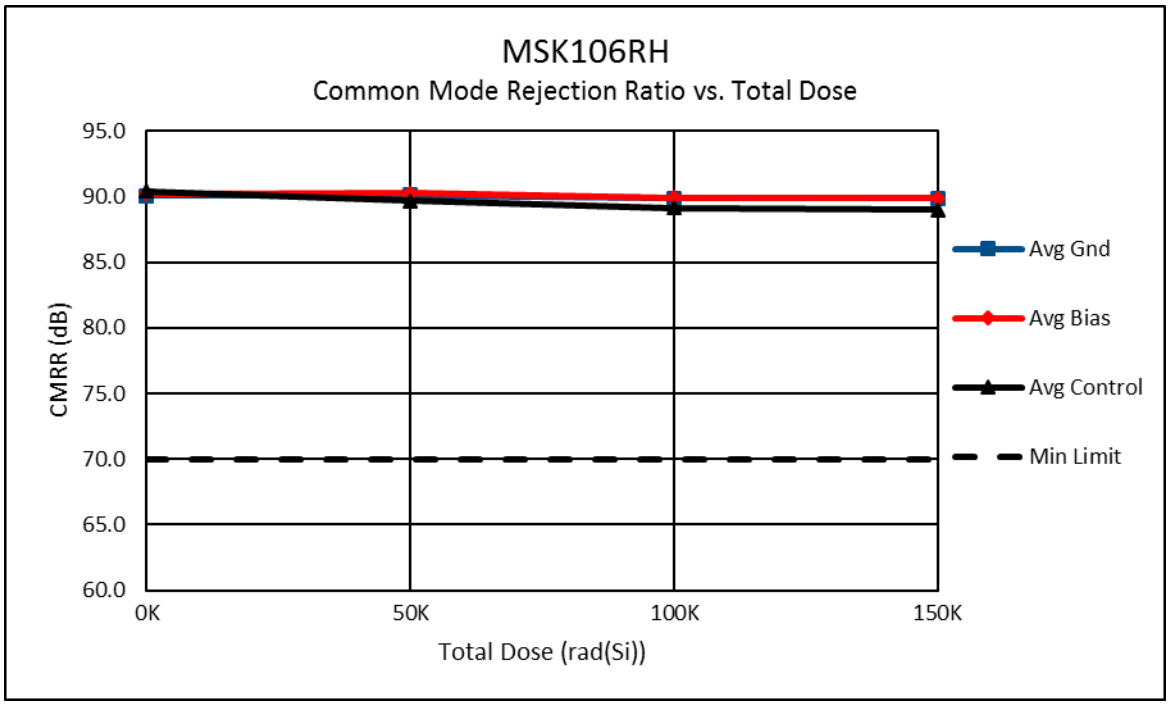

MSK106RH
+Output Short Circuit Current, RSC=5Ω vs. Total Dose
300.0
250.0
200.0
150.0
100.0
50.0
0.0
+ISC, RSC=5Ω (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

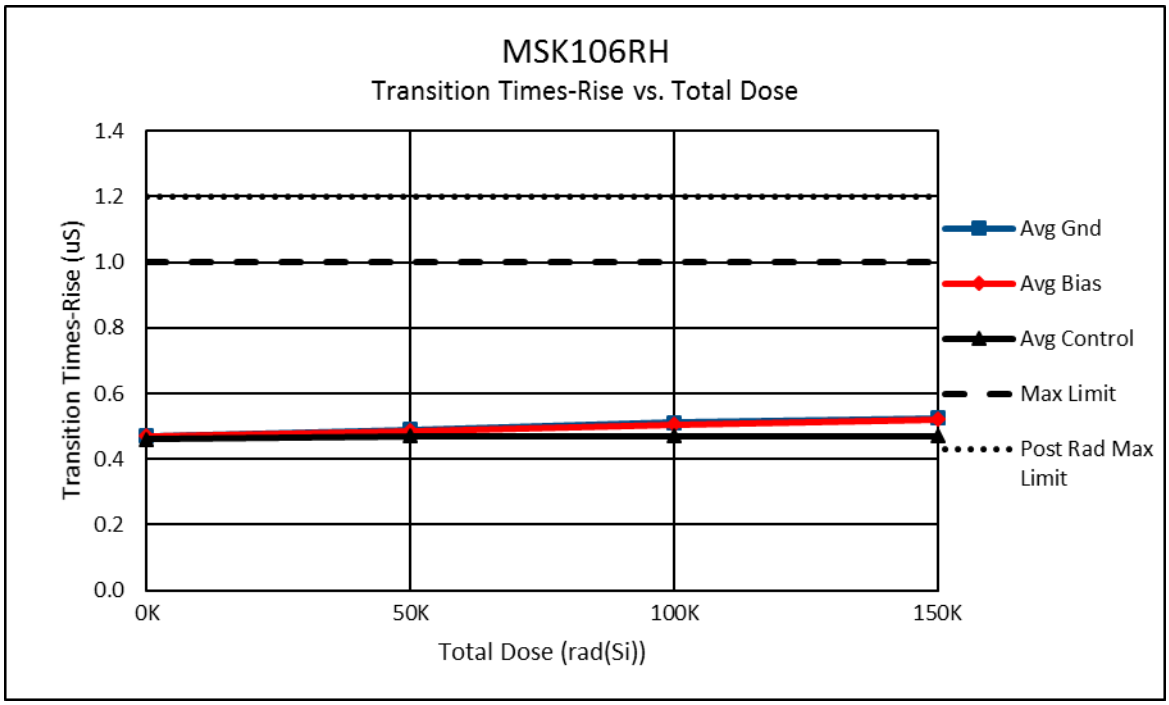

MSK106RH
-Output Short Circuit Current, RSC=5Ω vs. Total Dose
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
-300.0
-ISC, RSC=5Ω (mA)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Max Limit

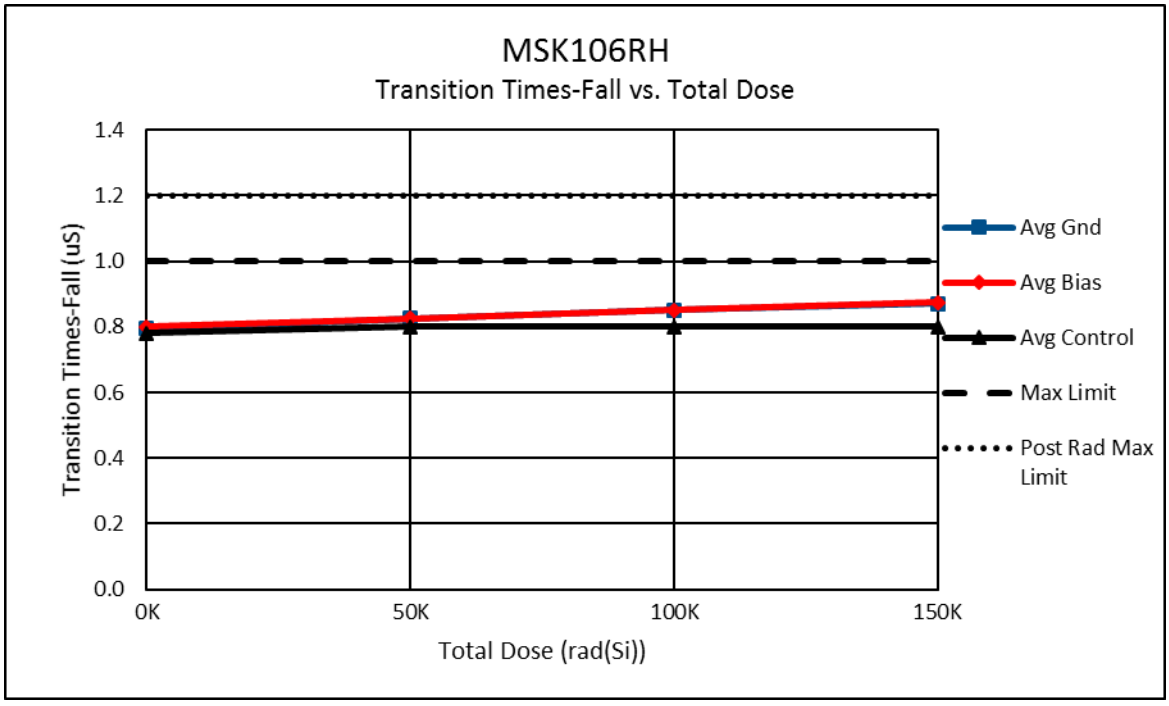

MSK106RH
+Slew Rate vs. Total Dose
2.5
2.0
1.5
1.0
0.5
0.0
+Slew Rate (V/uS)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Post Rad Min Limit

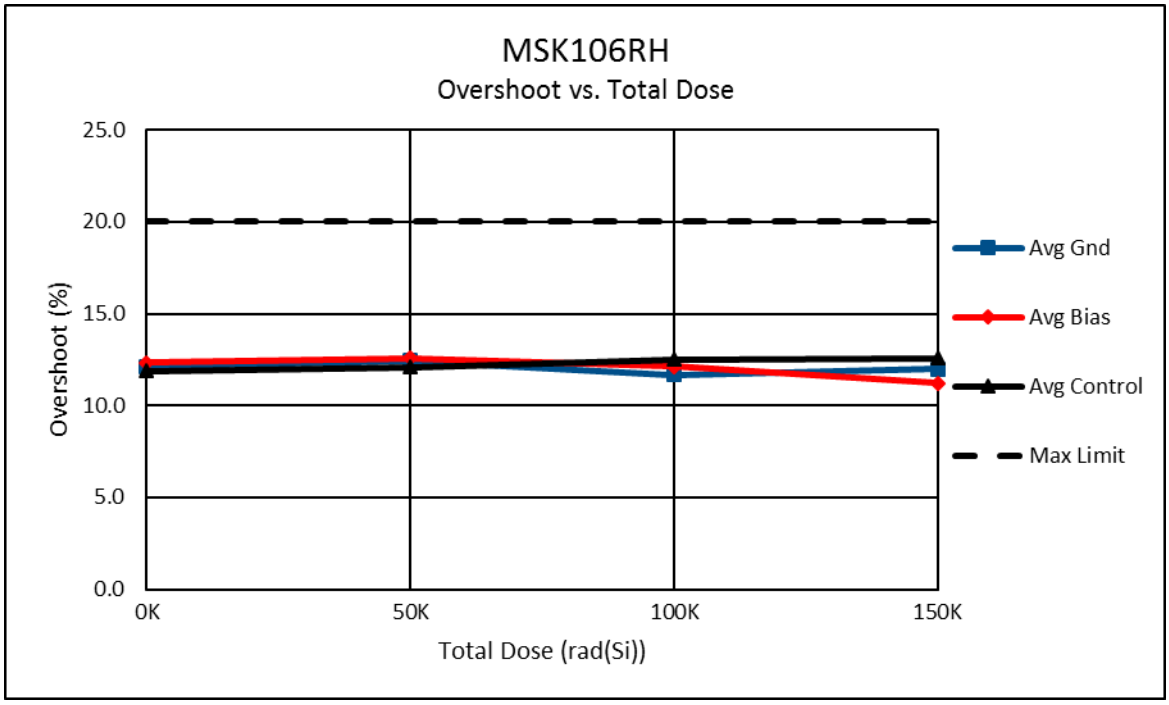

MSK106RH
-Slew Rate vs. Total Dose
2.5
2.0
1.5
1.0
0.5
0.0
-Slew Rate (V/uS)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit
Post Rad Min Limit


MSK106RH
Voltage Gain vs. Total Dose
112.0
110.0
108.0
106.0
104.0
102.0
100.0
98.0
96.0
94.0
Voltage Gain (dB)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit


MSK106RH
Common Mode Rejection Ratio vs. Total Dose
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
CMRR (dB)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Min Limit


MSK106RH
Transition Times-Rise vs. Total Dose
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Transition Times-Rise (uS)
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit
Post Rad Max Limit


MSK106RH
Transition Times-Fall vs. Total Dose
Transition Times-Fall (uS)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit
Post Rad Max Limit


MSK106RH
Overshoot vs. Total Dose
Overshoot (%)
25.0
20.0
15.0
10.0
5.0
0.0
0K
50K
100K
150K
Total Dose (rad(Si))
Avg Gnd
Avg Bias
Avg Control
Max Limit

Total Dose Radiation Test Report

MSK 106RH

Radiation Hardened High Power Op Amp

January 3, 2005 – TID (First Test)
Updated on August 4, 2006
Updated on January 25, 2008 (Second Test)
March 18, 2010 TID (Third Test)
April 24, 2013 – TID (Fourth Test)

B. Erwin
F. Freytag

M.S. Kennedy Corporation
Liverpool, NY

I. Introduction:

The total dose radiation test plan for the MSK 106RH was developed to qualify the device as radiation hardened up to 100 Krad(Si). The testing was performed beyond 100 Krad(Si) to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the hybrid, but simply offers designers insight to the critical parameter-shifts beyond the specified total dose level.

MIL-STD-883 Method 1019.7 and ASTM F1892-06 were used as guidelines in the development and implementation of the total dose test plan for the MSK 106RH.

II. Radiation Source:

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. Dosimetry was performed prior to device irradiation and the dose rate was determined to be 96 rads(Si)/sec. The total dose schedule can be found in Table I.

III. Test Setup:

All test samples were subjected to Group A Electrical Test in accordance with the device data sheet. In addition, all devices received 320 hours of burn-in per MIL-STD-883 Method 1015 and were electrically tested prior to irradiation. For test platform verification, one control device was tested at 25°C.

The devices were vertically aligned with the radiation source and enclosed in a Pb/Al container during irradiation to minimize dose enhancement effects. Five devices were kept under bias during irradiation. Five devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and were transported to the MSK automatic electrical test platform and tested IAW MSK device data sheet. Testing was performed on irradiated devices, as well as the control device, at each total dose level. Electrical tests were completed within one hour of irradiation. Subsequent dosing was performed within two hours.

IV. Data:

All performance curves are averaged from the test results of the biased and unbiased devices respectively.

V. Summary:

The devices performed well with respect to TID, qualifying to 100 Krad(Si) by the 99/90 statistical analysis of the test data.

Quiescent current decreased approximately 20 percent at 150 KRad(Si).

Input bias current increased significantly, but stayed within specification limits to 150 Krads(Si).

Positive and negative slew rate decreased as testing progressed to 150 Krads(Si). However, slew rate values stayed within pre-irradiation limits up to 150Krads(Si). Final slew rate was within post irradiation limits at 150 Krads(Si).

Transition times showed a slight increase, but stayed within pre-irradiation limits throughout testing.

MSK 106RH Biased/Unbiased Dose Rate Schedule

Dosimetry Equipment
Bruker Biospin # 0162

Irradiation Date
4/24/2013

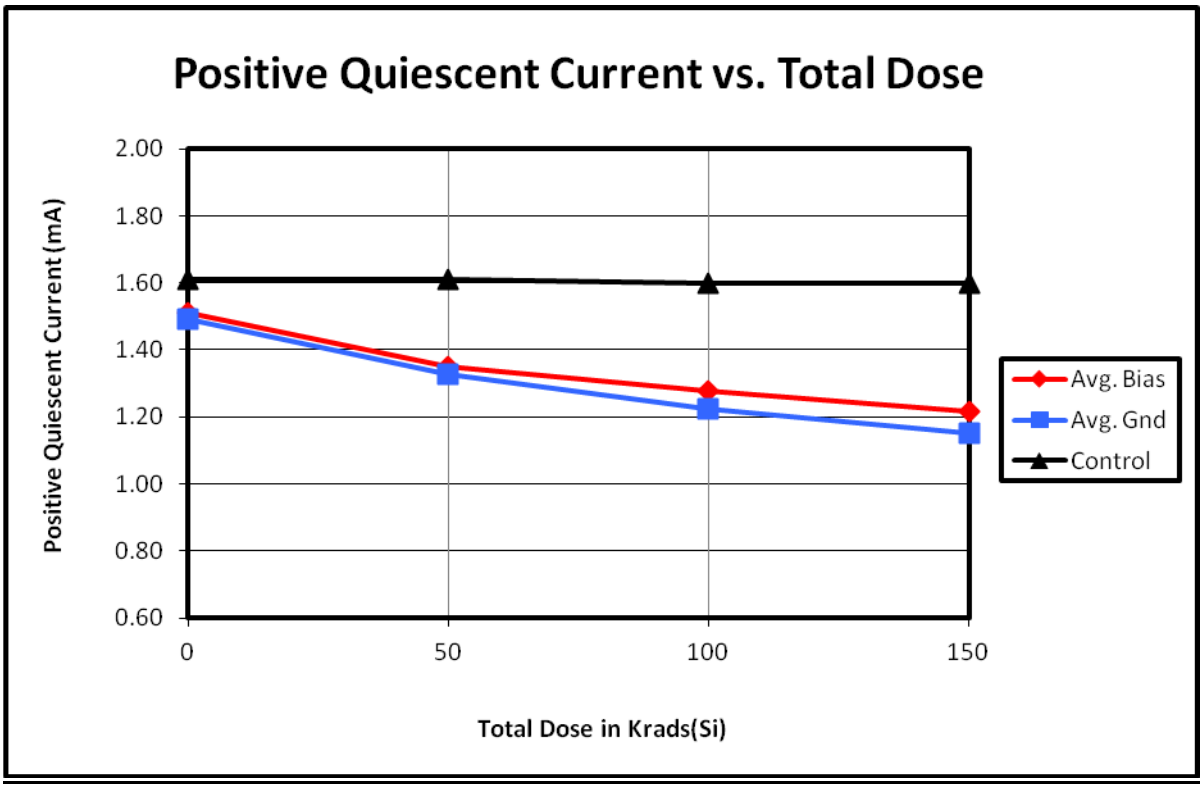
Exposure Length (min:sec)	Incremental Dose rads(Si)	Cumulative Dose rads(Si)
08:57	51,552	51,552
08:57	51,552	103,104
08:57	51,552	154,656

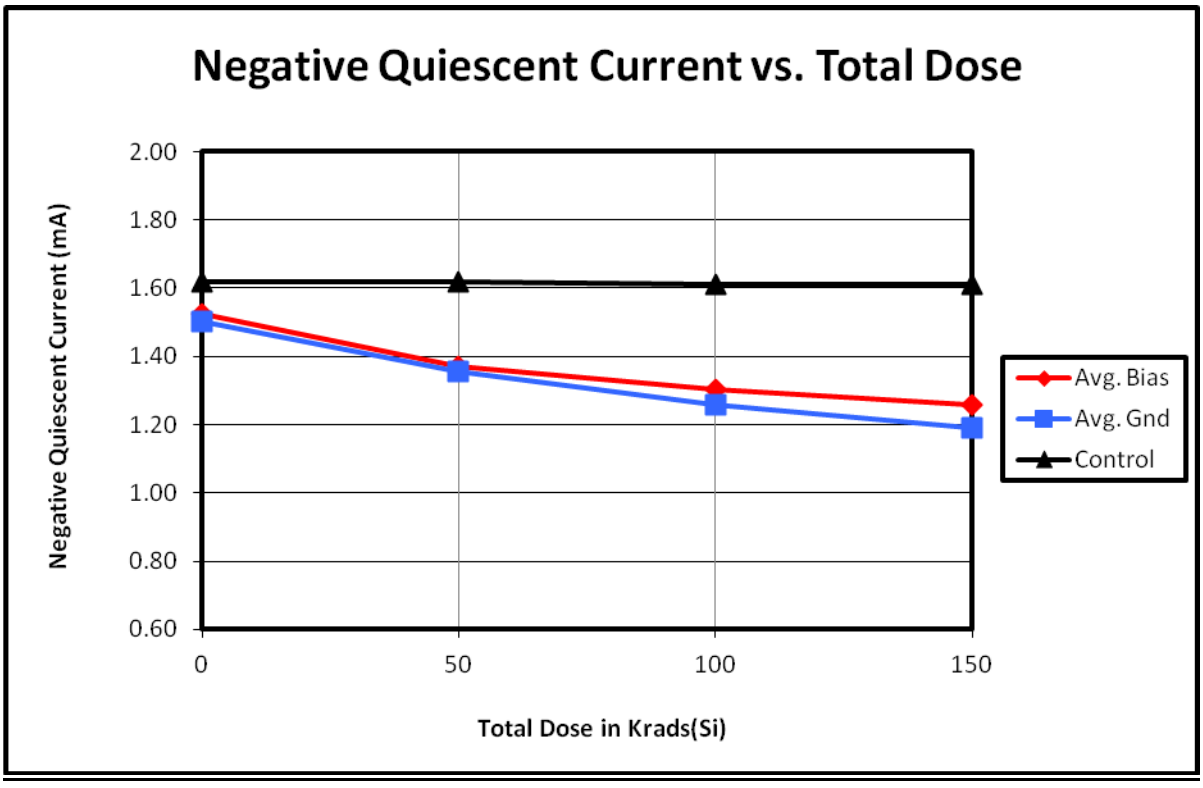
Biased S/N – 0360, 0361, 0362, 0363, 0365

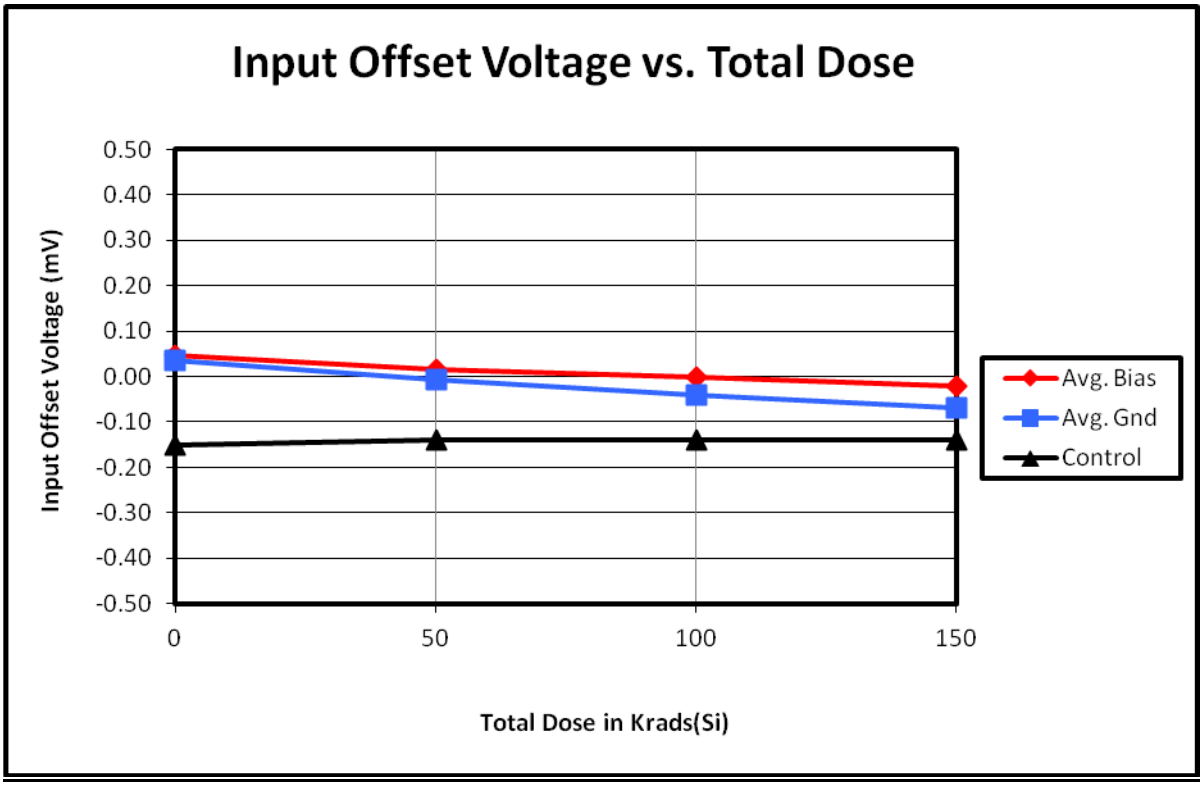
Unbiased S/N – 0366, 0367, 0368, 0370, 0371

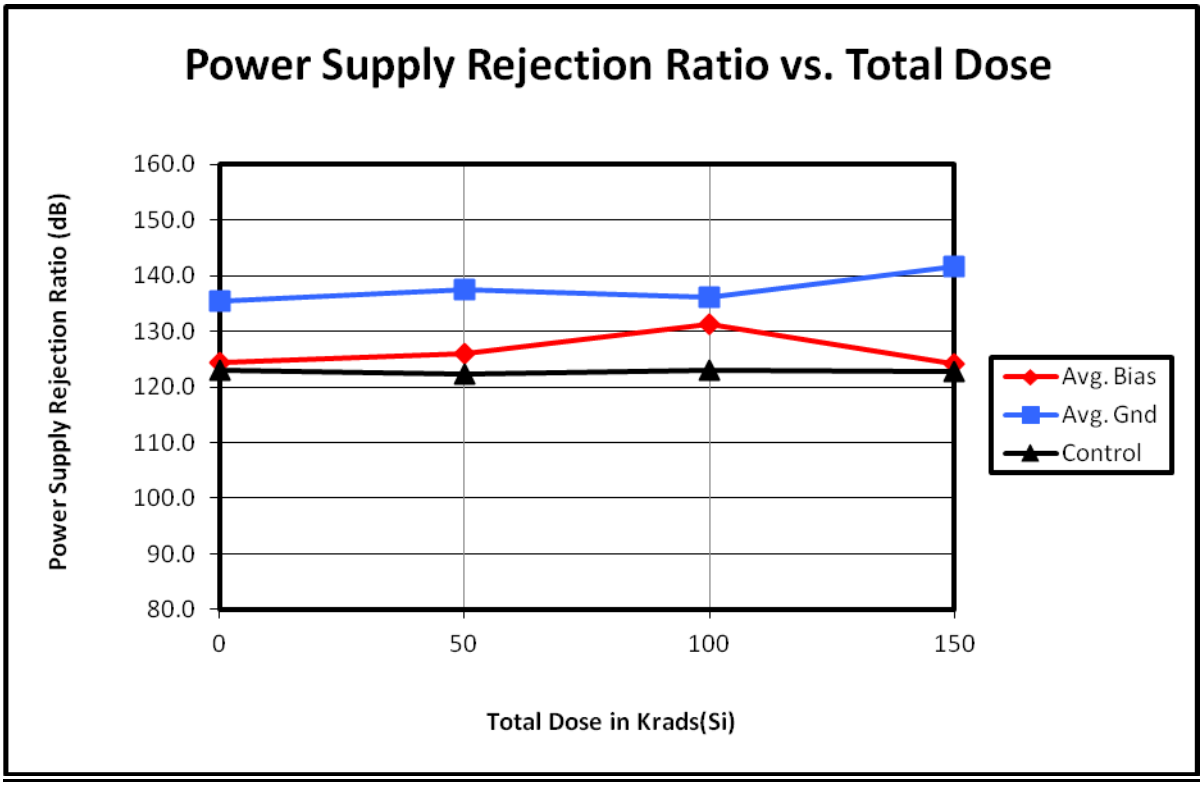
Table 1

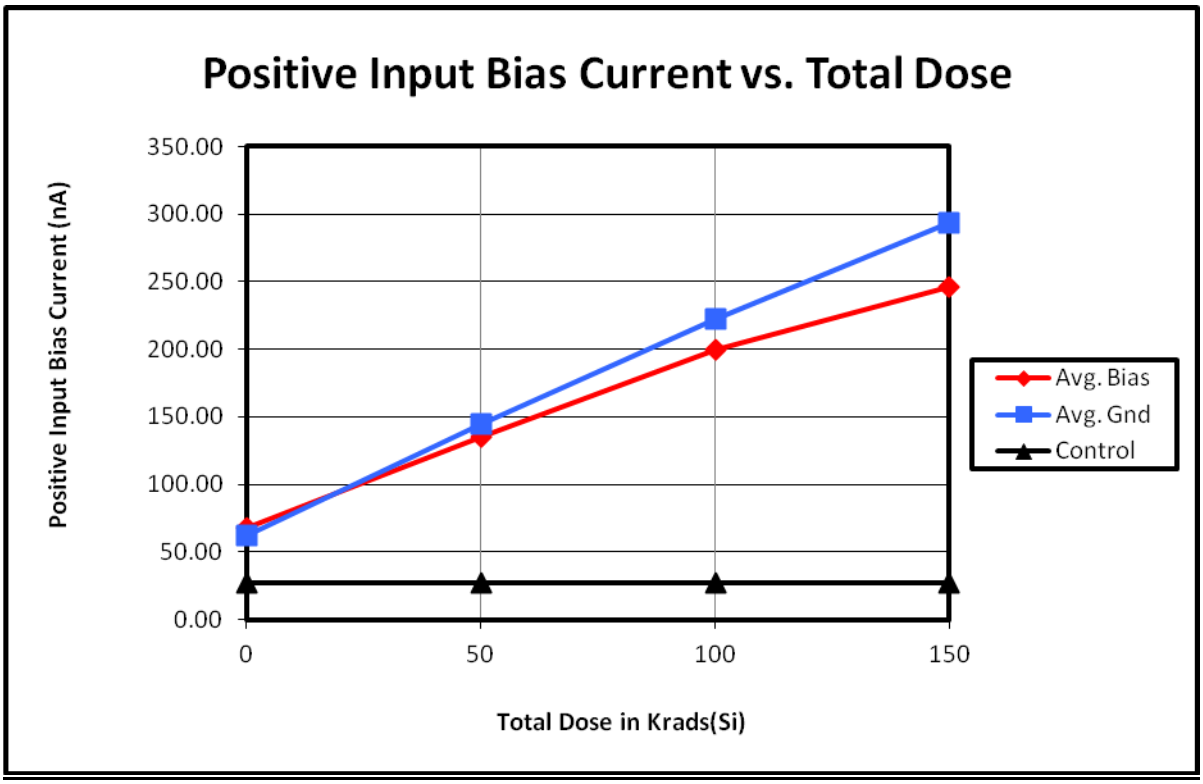
Dose Time, Incremental Dose and Total Cumulative Dose

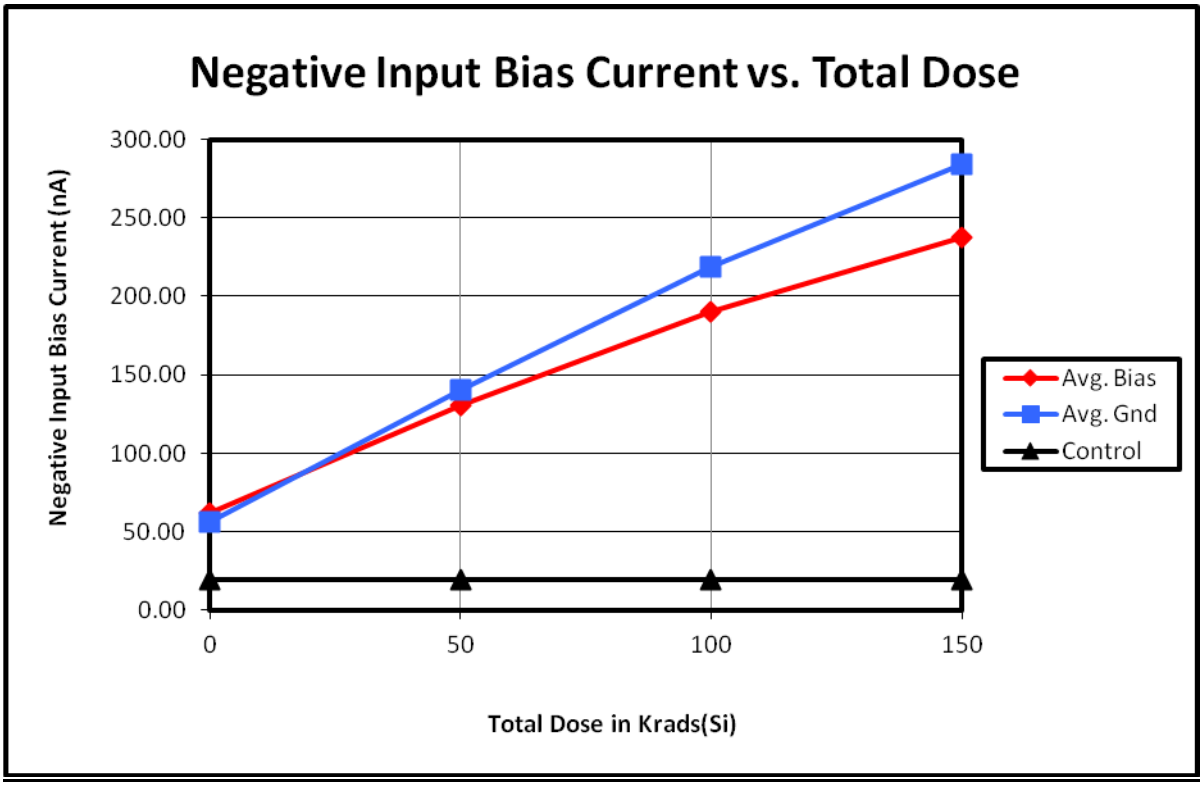

Positive Quiescent Current vs. Total Dose
Positive Quiescent Current (mA)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

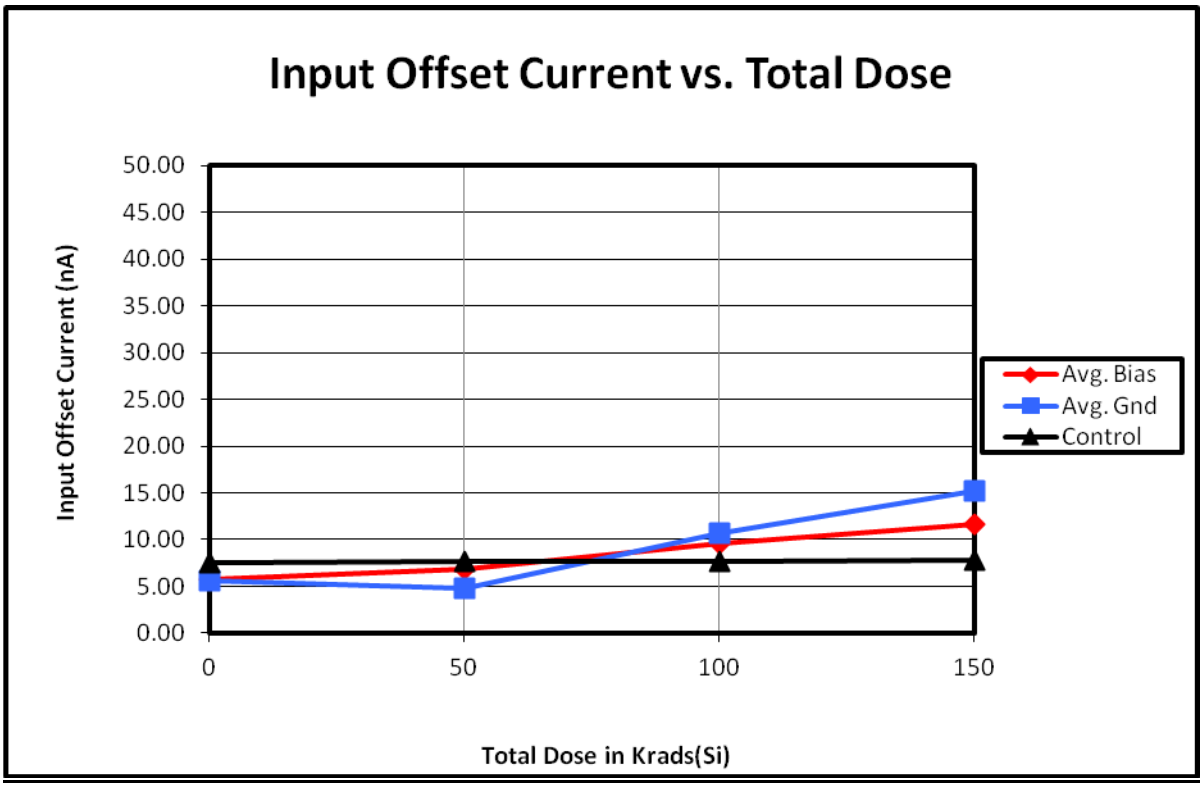

Negative Quiescent Current vs. Total Dose
Negative Quiescent Current (mA)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

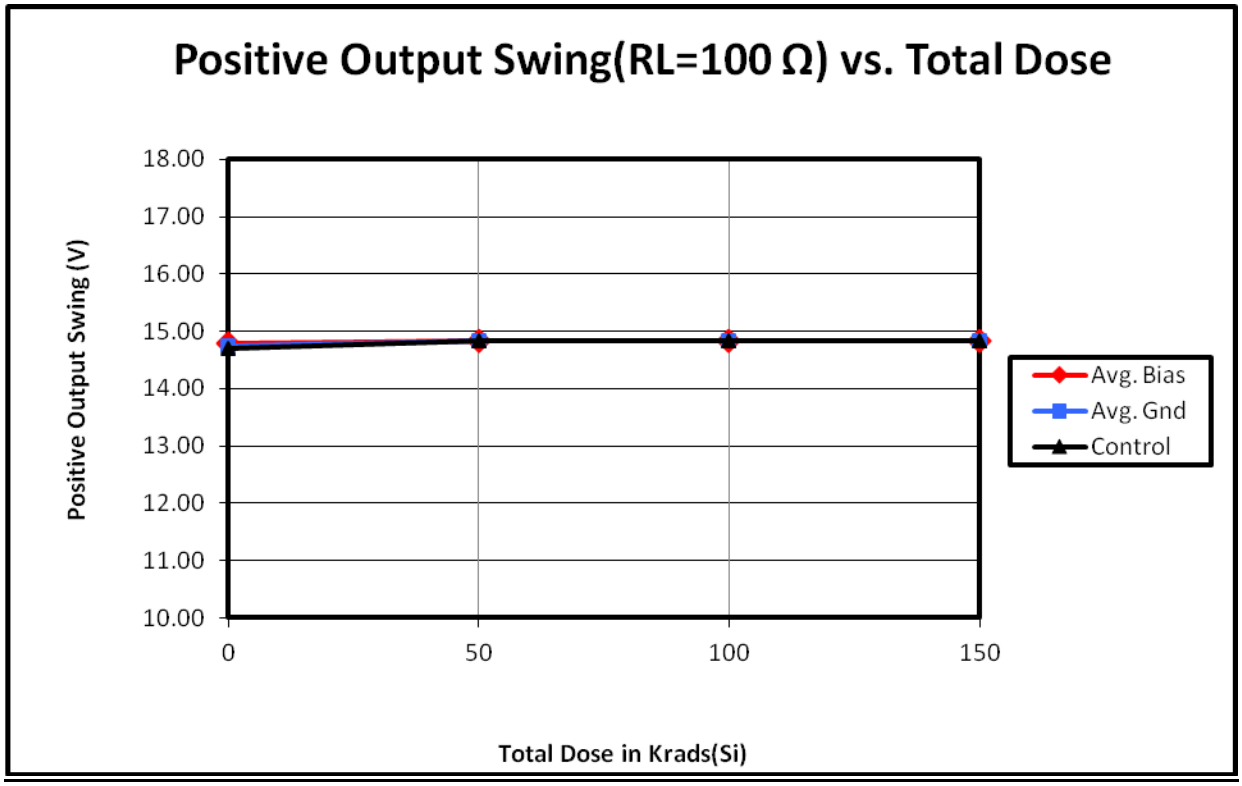

Input Offset Voltage vs. Total Dose
Input Offset Voltage (mV)
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

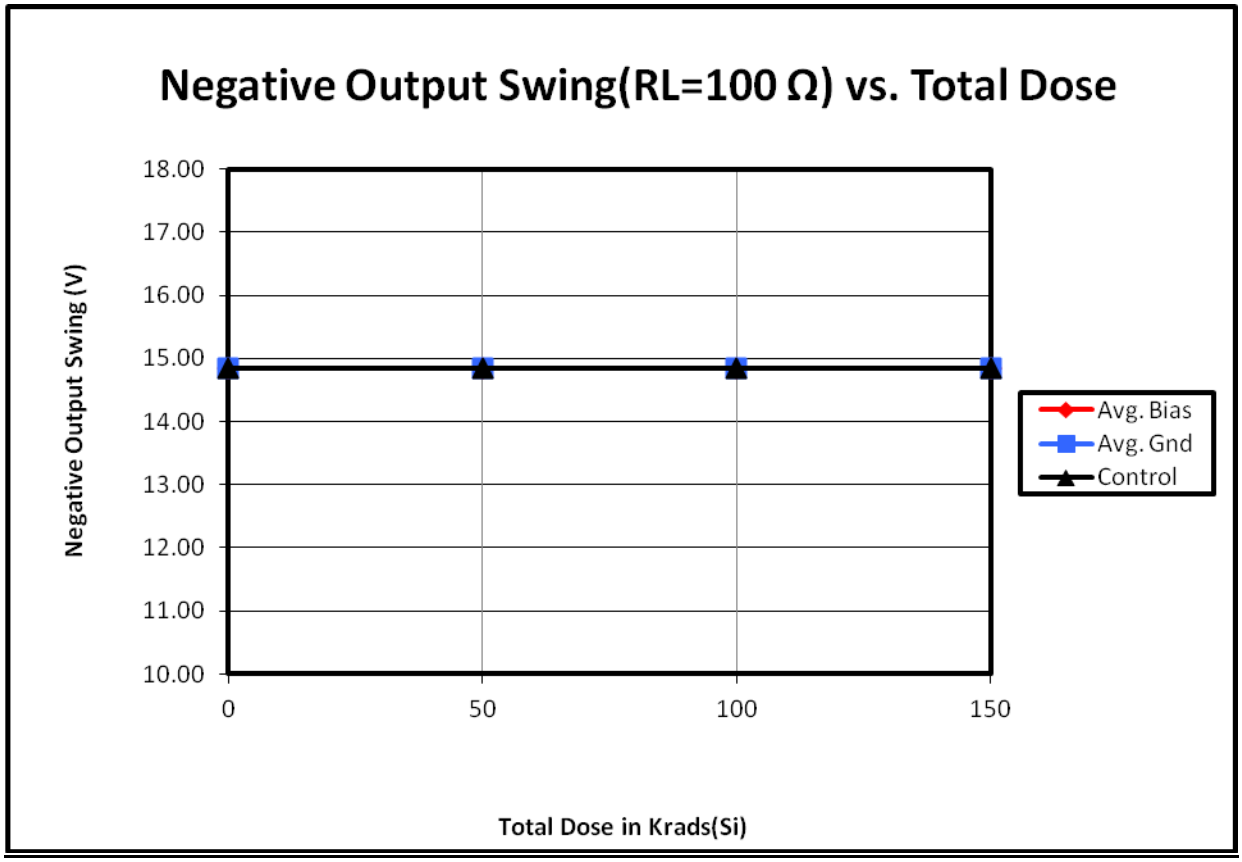

Power Supply Rejection Ratio vs. Total Dose
Power Supply Rejection Ratio (dB)
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

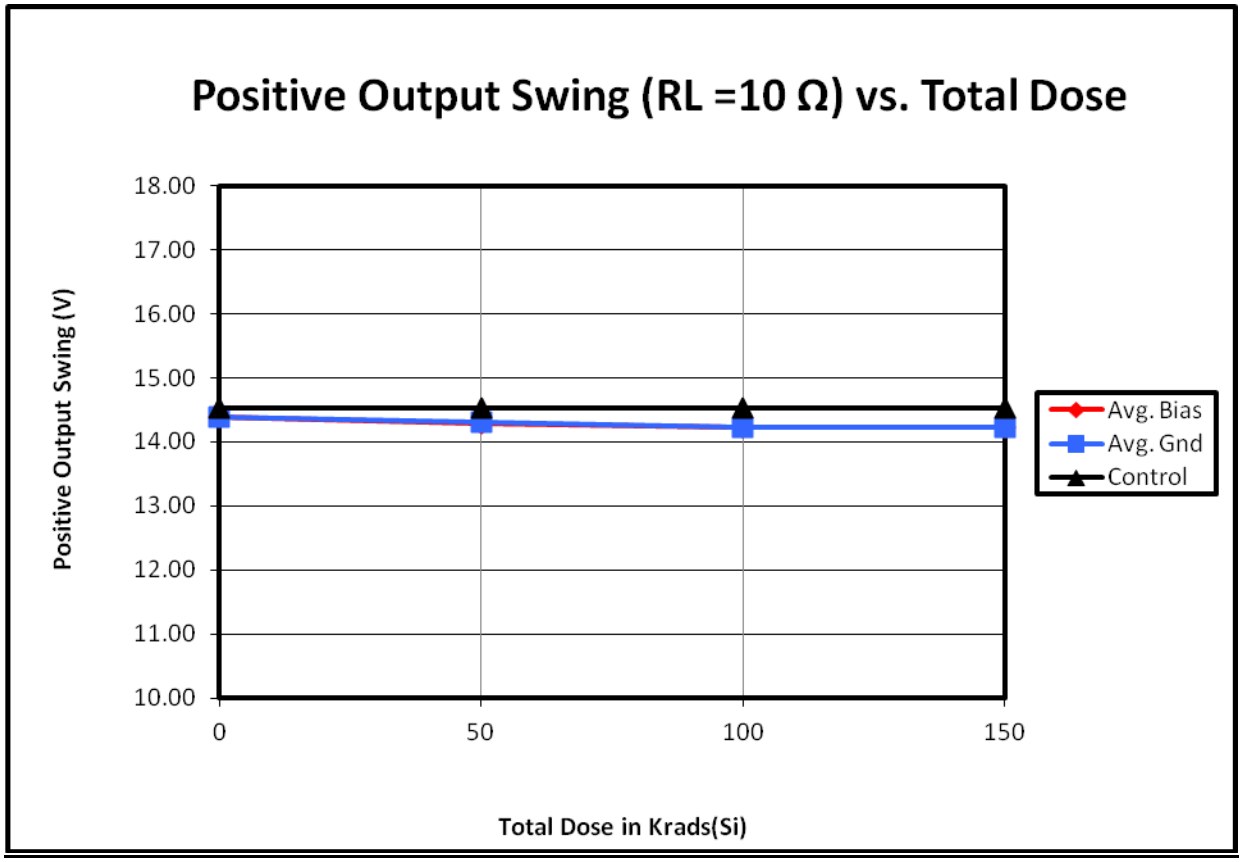

Positive Input Bias Current vs. Total Dose
Positive Input Bias Current (nA)
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

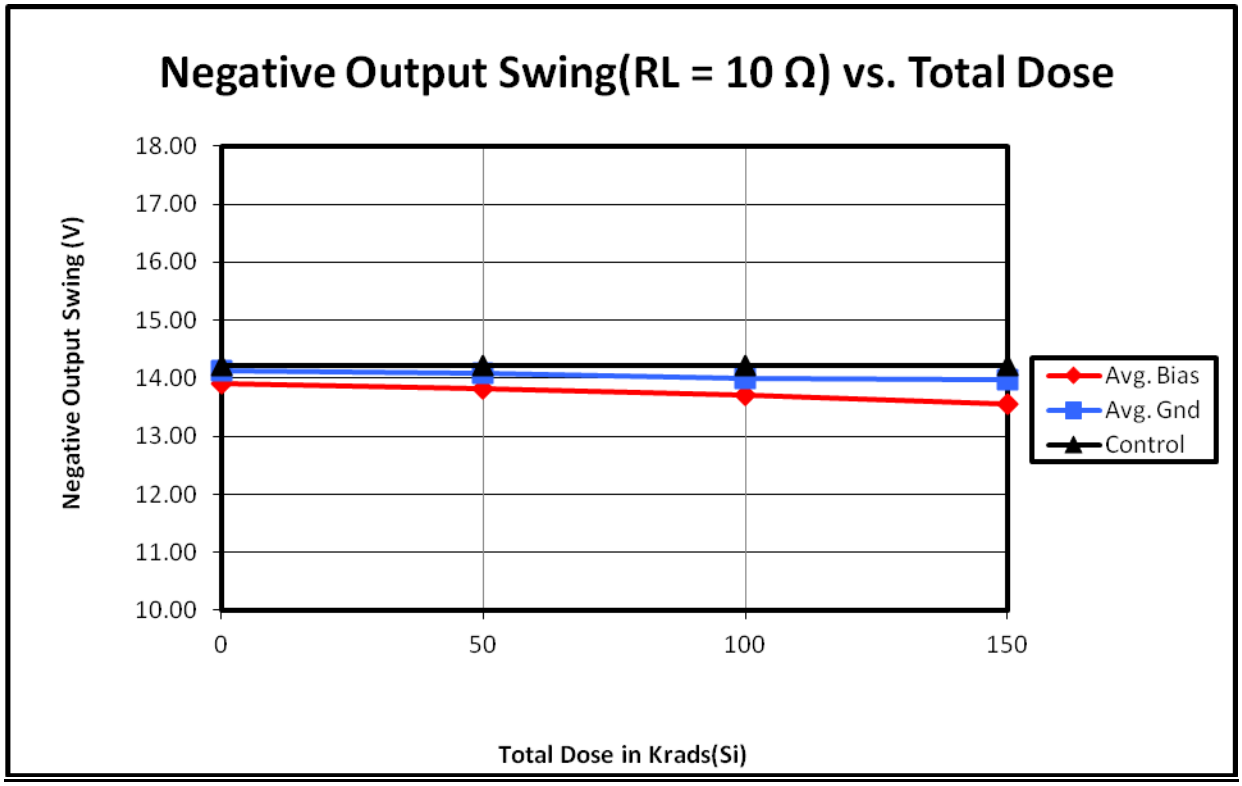

Negative Input Bias Current vs. Total Dose
Negative Input Bias Current (nA)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

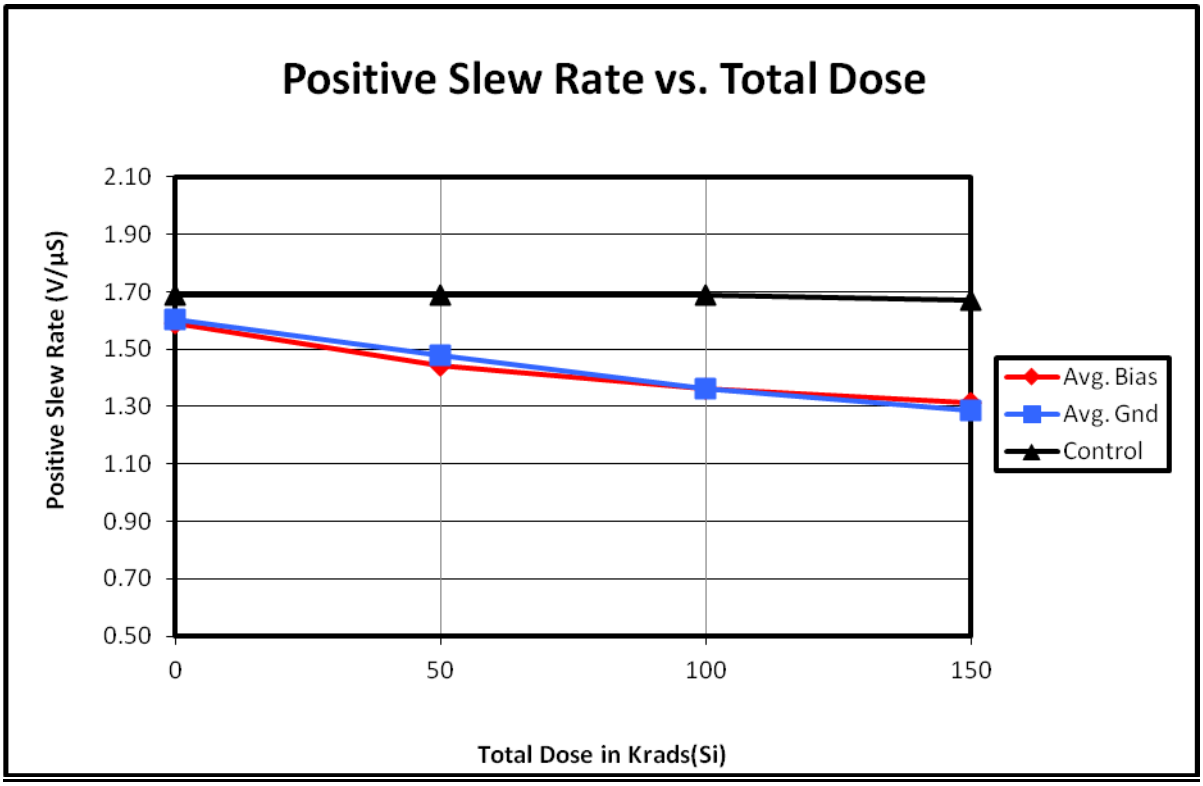

Input Offset Current vs. Total Dose
Input Offset Current (nA)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

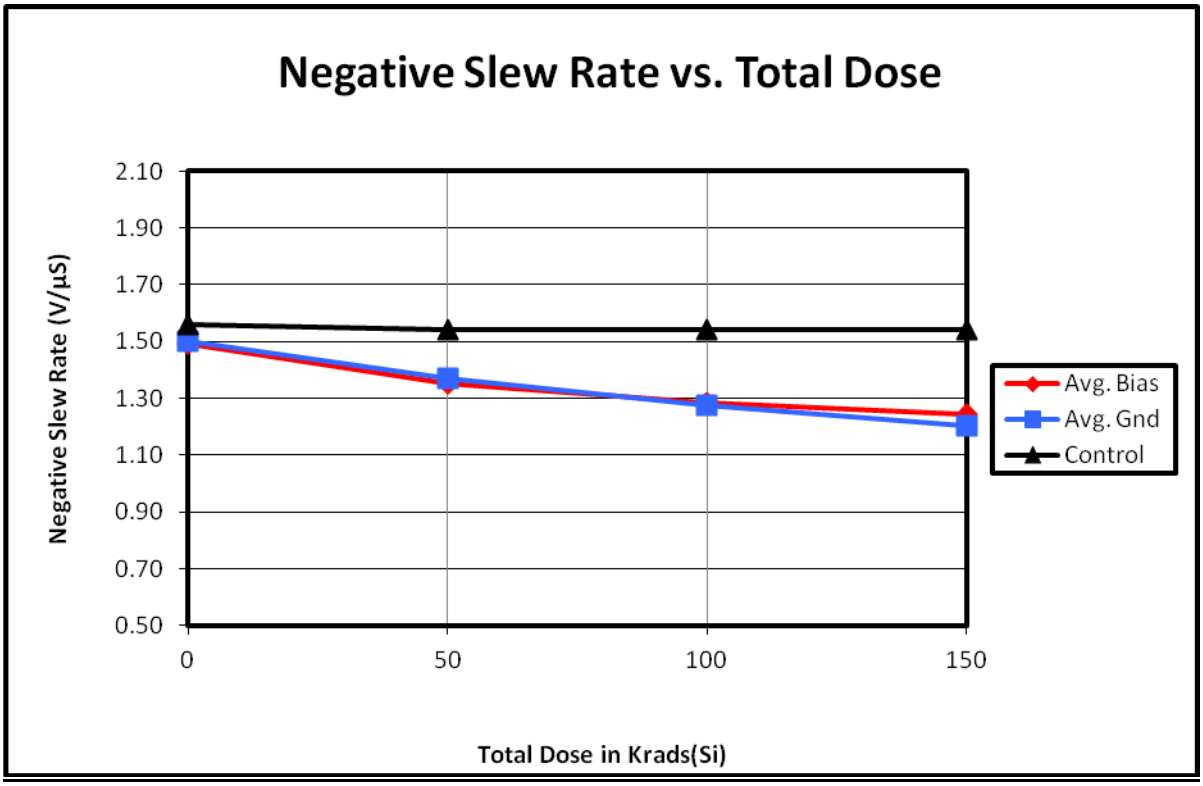

Positive Output Swing(RL=100 Ω) vs. Total Dose
Positive Output Swing (V)
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

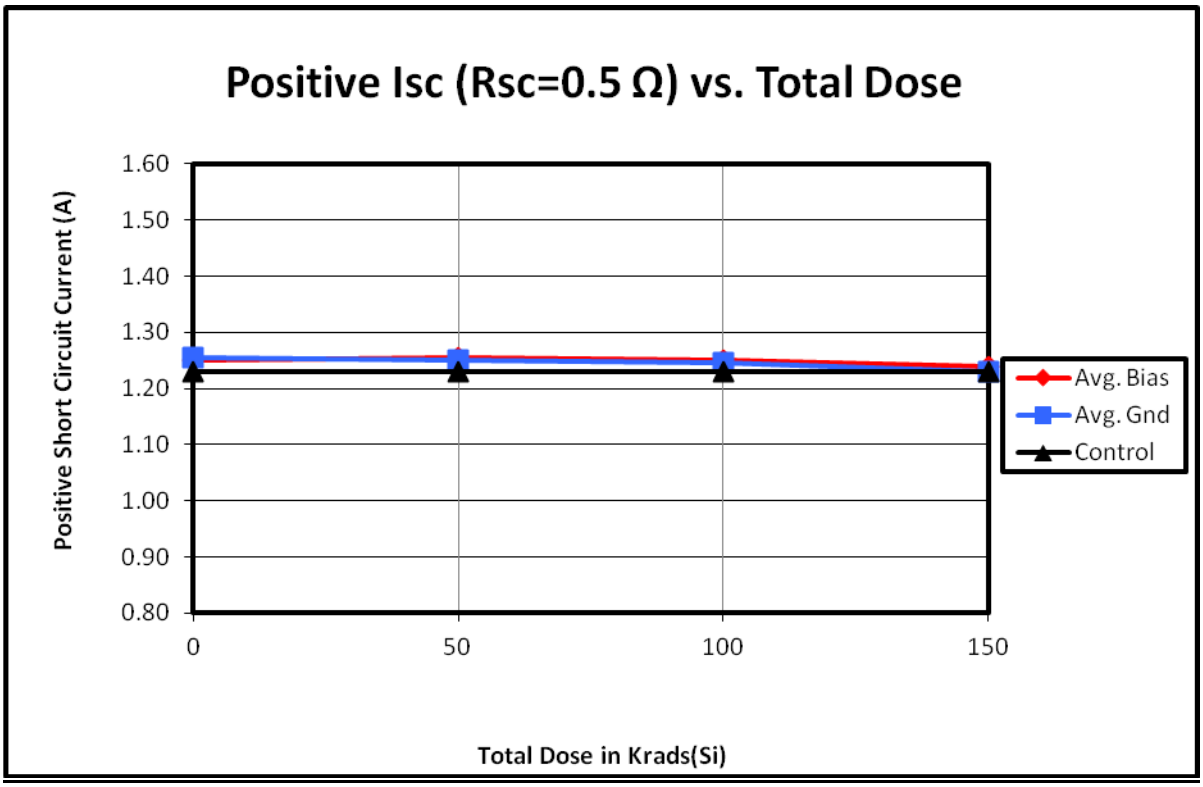

Negative Output Swing(RL=100 Ω) vs. Total Dose
Negative Output Swing (V)
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

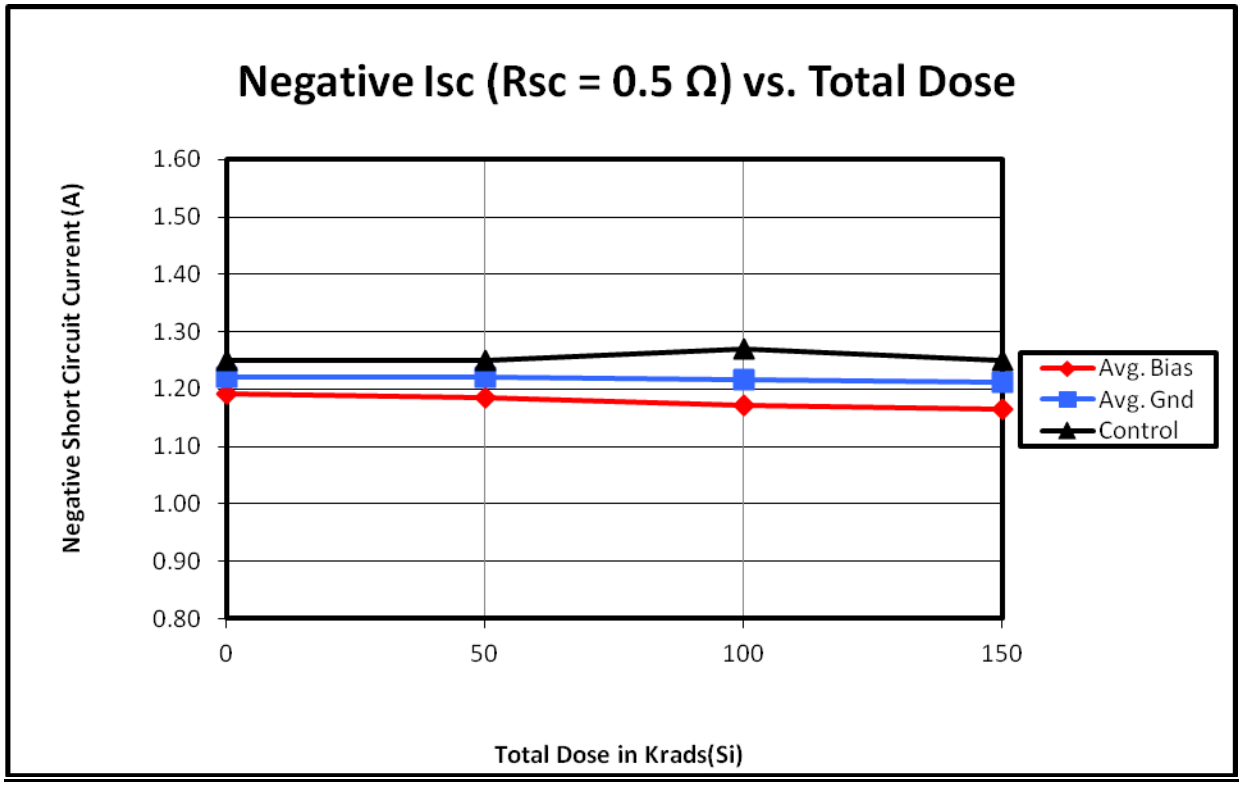

Positive Output Swing (RL =10 Ω) vs. Total Dose
Positive Output Swing (V)
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

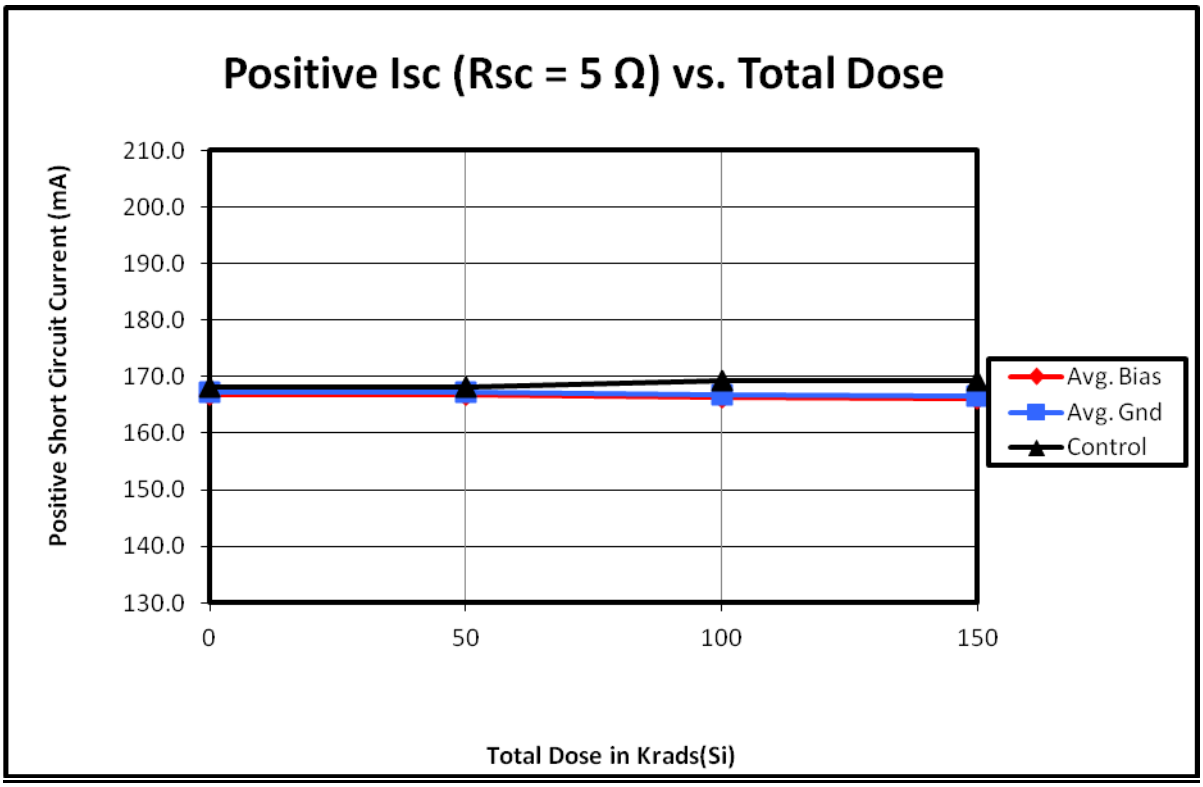

Negative Output Swing(RL = 10 Ω) vs. Total Dose
Negative Output Swing (V)
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

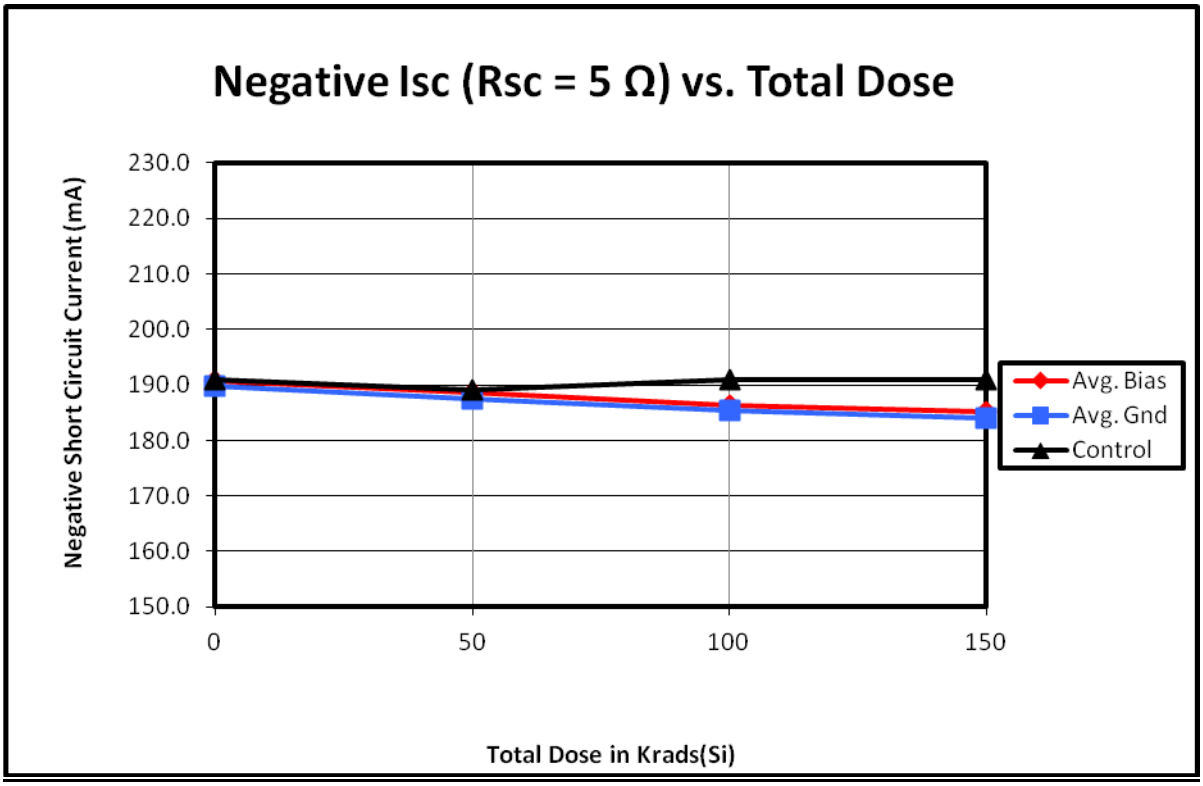

Positive Slew Rate vs. Total Dose
Positive Slew Rate (V/µS)
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

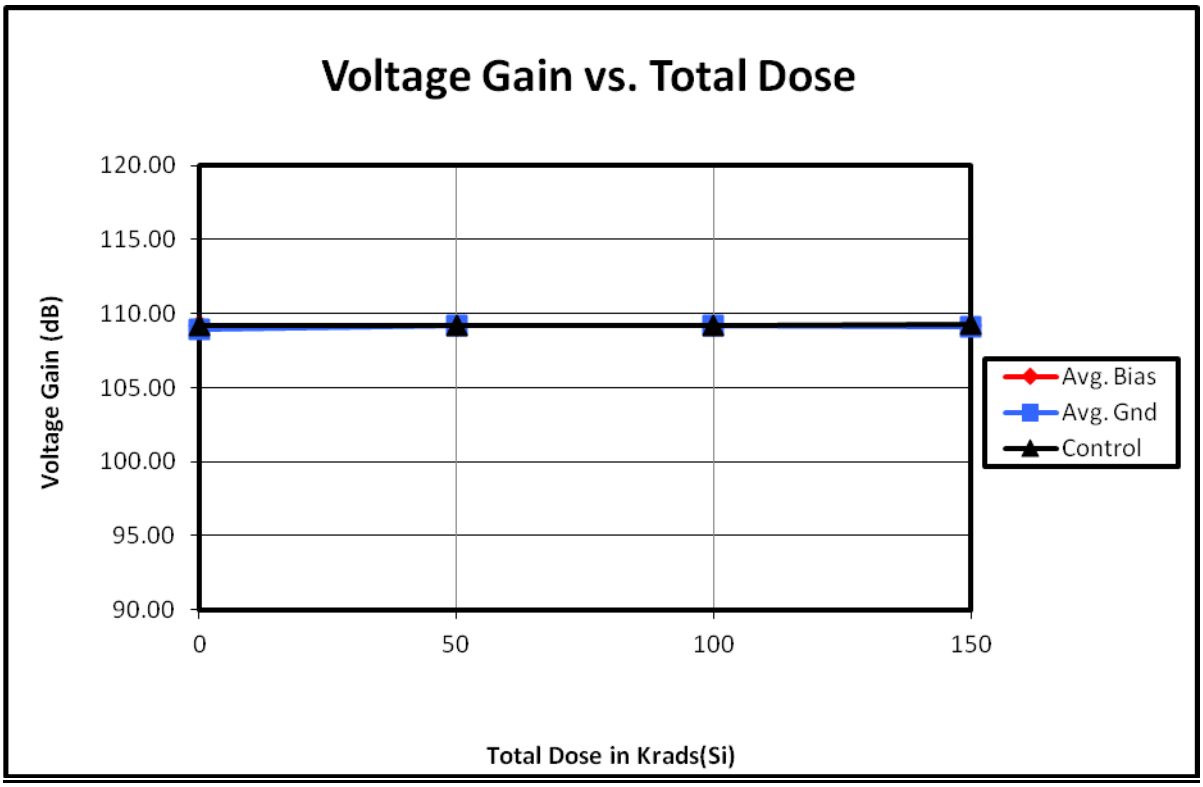

Negative Slew Rate vs. Total Dose
Negative Slew Rate (V/µS)
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

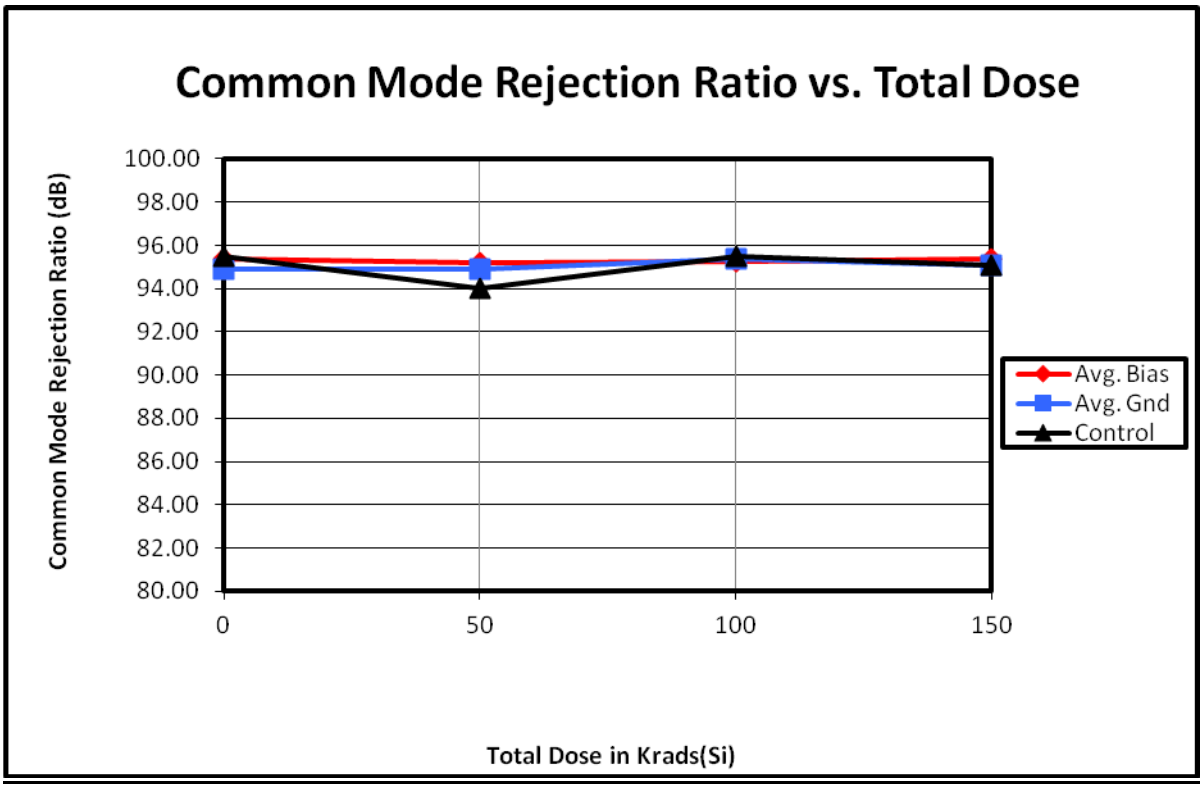

Positive Isc (Rsc=0.5 Ω) vs. Total Dose
Positive Short Circuit Current (A)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

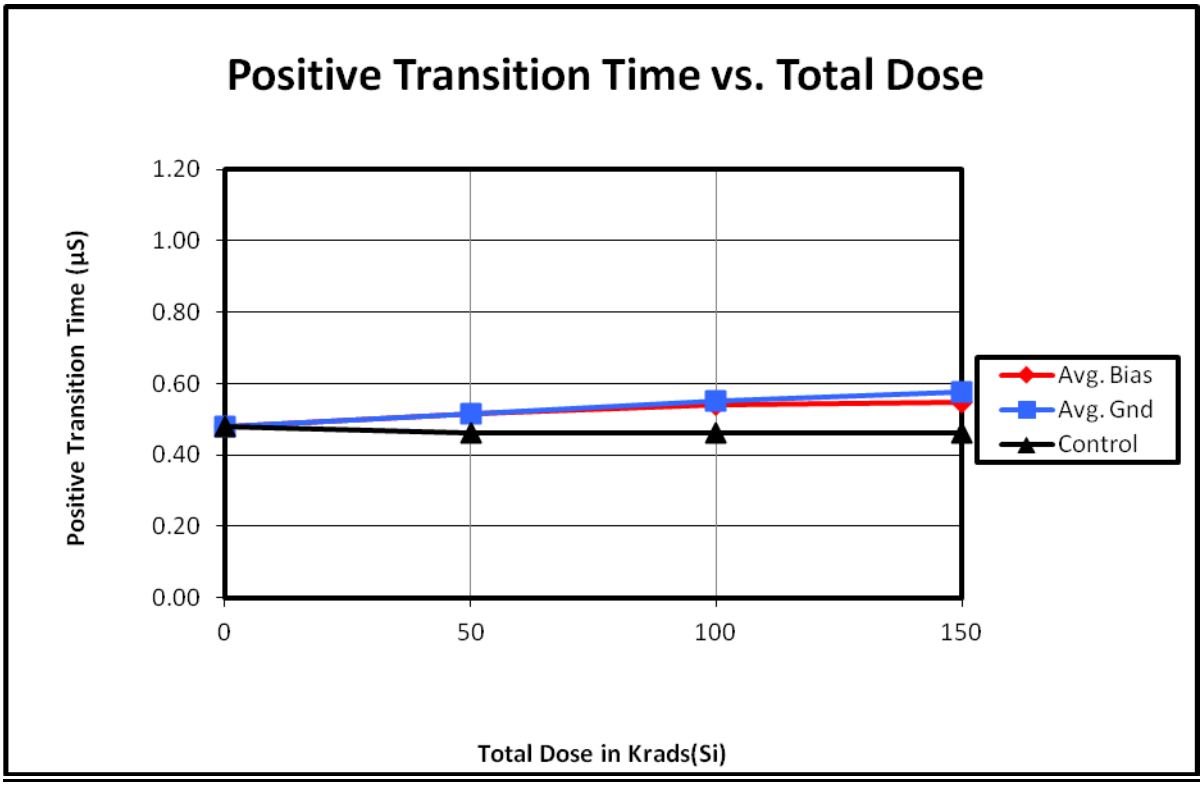

Negative Isc (Rsc = 0.5 Ω) vs. Total Dose
Negative Short Circuit Current (A)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

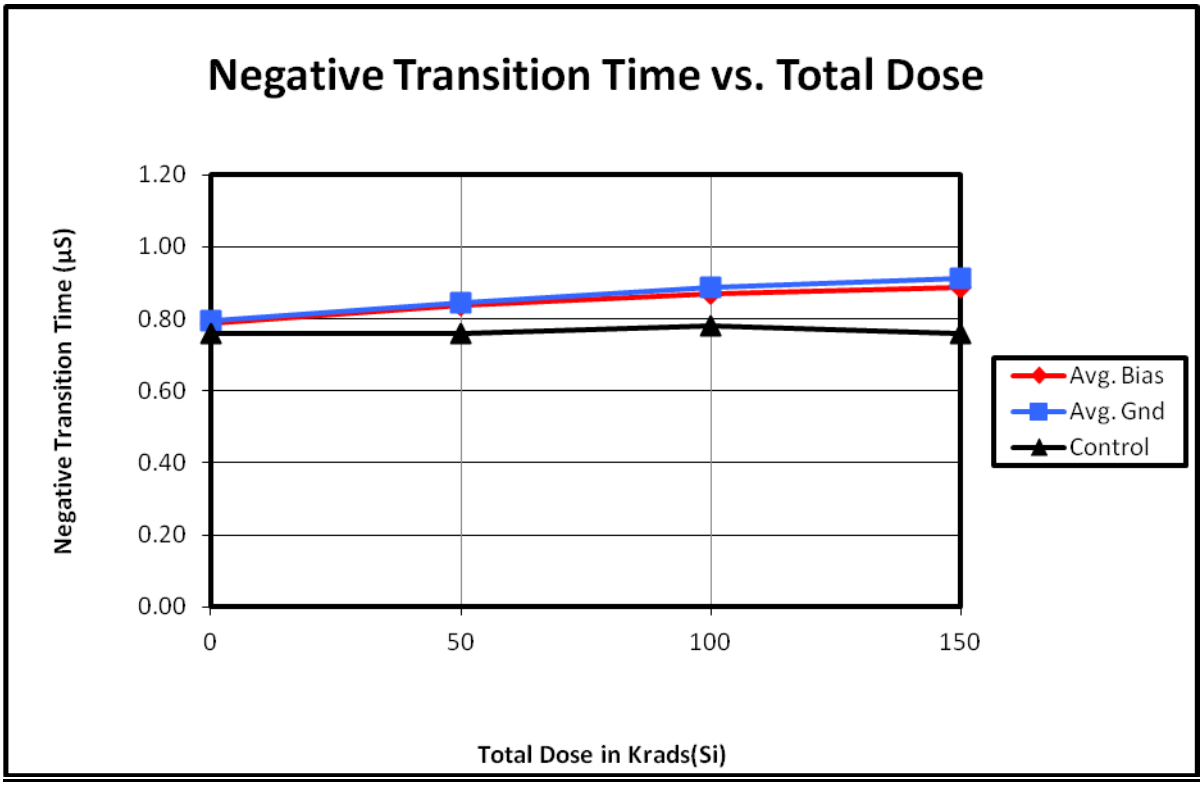

Positive Isc (Rsc = 5 Ω) vs. Total Dose
Positive Short Circuit Current (mA)
210.0
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

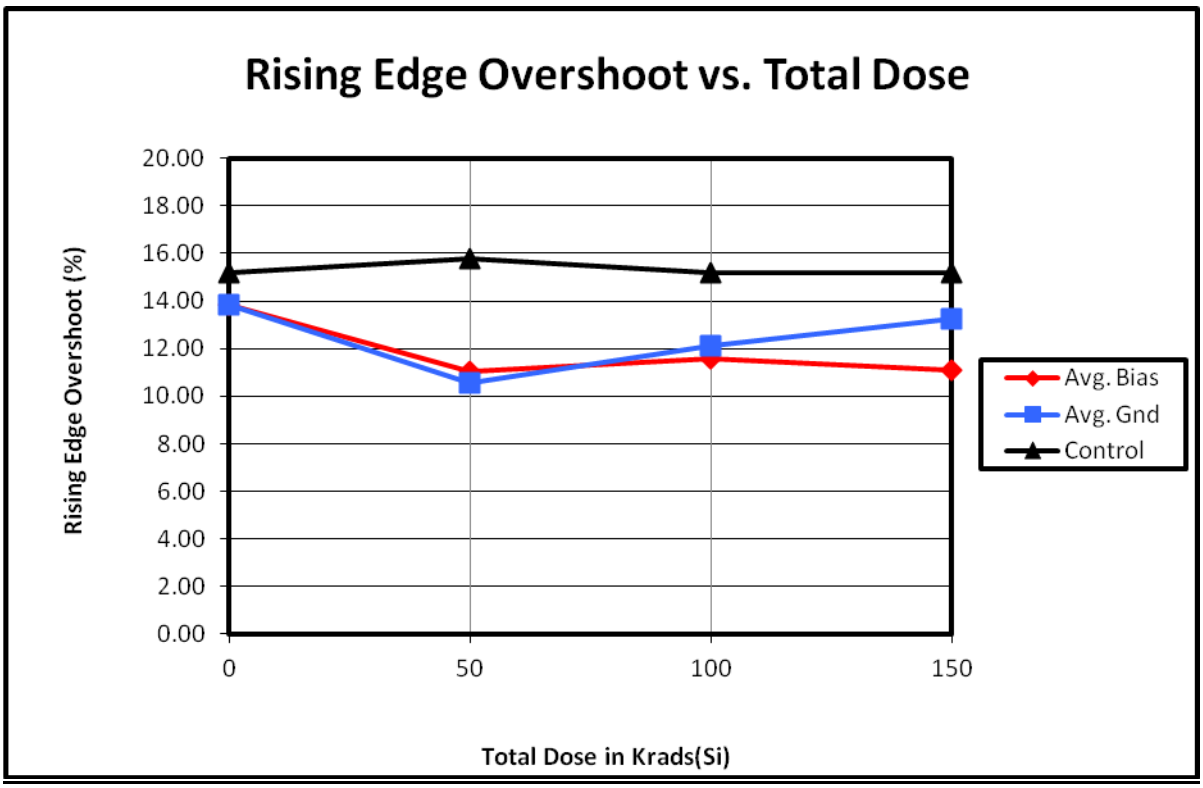

Negative Isc (Rsc = 5 Ω) vs. Total Dose
Negative Short Circuit Current (mA)
230.0
220.0
210.0
200.0
190.0
180.0
170.0
160.0
150.0
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

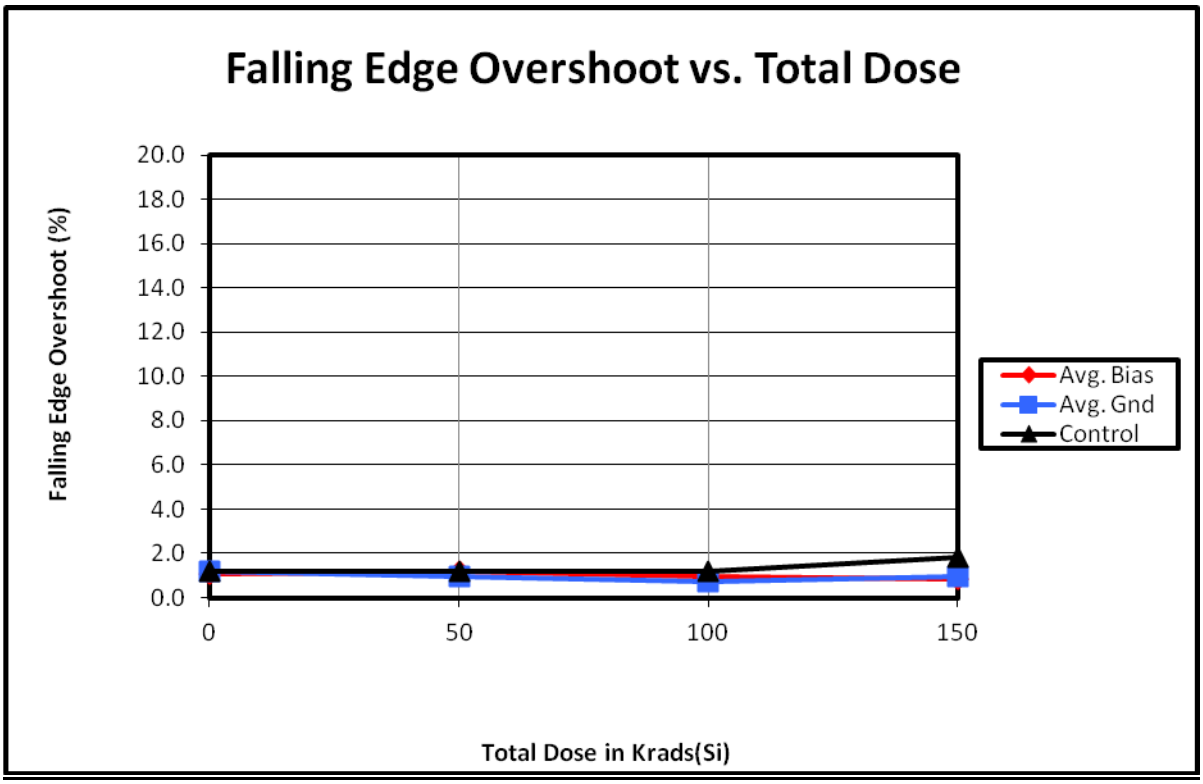

Voltage Gain vs. Total Dose
Voltage Gain (dB)
120.00
115.00
110.00
105.00
100.00
95.00
90.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Common Mode Rejection Ratio vs. Total Dose
Common Mode Rejection Ratio (dB)
100.00
98.00
96.00
94.00
92.00
90.00
88.00
86.00
84.00
82.00
80.00
0
50
100
150
Avg. Bias
Avg. Gnd
Control
Total Dose in Krads(Si)


Positive Transition Time vs. Total Dose
Positive Transition Time (µS)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
Avg. Bias
Avg. Gnd
Control
Total Dose in Krads(Si)


Negative Transition Time vs. Total Dose
Negative Transition Time (µS)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Rising Edge Overshoot vs. Total Dose
Rising Edge Overshoot (%)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
50
100
150
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Falling Edge Overshoot vs. Total Dose
Falling Edge Overshoot (%)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
50
100
150
Avg. Bias
Avg. Gnd
Control
Total Dose in Krads(Si)

Total Dose Radiation Test Report

MSK 106RH

Radiation Hardened High Power Op Amp

January 3, 2005
Updated on August 4, 2006
Updated on January 25, 2008 (Second Test)
March 18, 2010 (Third Test)

B. Erwin
R. Wakeman

M.S. Kennedy Corporation
Liverpool, NY

I. Introduction:

The total dose radiation test plan for the MSK 106RH was developed to qualify the device as radiation hardened up to 100 Krad(Si). The testing was performed beyond 100 Krad(Si) to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the hybrid, but simply offers designers insight to the critical parameter-shifts beyond the specified total dose level.

MIL-STD-883 Method 1019.7 and ASTM F1892-06 were used as guidelines in the development and implementation of the total dose test plan for the MSK 106RH.

II. Radiation Source:

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. Dosimetry was performed prior to device irradiation and the dose rate was determined to be 142 rads(Si)/sec. The total dose schedule can be found in Table I.

III. Test Setup:

All test samples were subjected to Group A Electrical Test in accordance with the device data sheet. In addition, all devices received 320 hours of burn-in per MIL-STD-883 Method 1015 and were electrically tested prior to irradiation. For test platform verification, one control device was tested at 25°C.

The devices were vertically aligned with the radiation source and enclosed in a Pb/Al container during irradiation to minimize dose enhancement effects. Five devices were kept under bias during irradiation. Five devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and were transported to the MSK automatic electrical test platform and tested IAW MSK device data sheet. Testing was performed on irradiated devices, as well as the control device, at each total dose level. Electrical tests were completed within one hour of irradiation. Subsequent dosing was performed within two hours.

IV. Data:

All performance curves are averaged from the test results of the biased and unbiased devices respectively.

V. Summary:

The devices performed well with respect to TID, qualifying to 100 Krad(Si) by the 99/90 statistical analysis of the test data.

Devices did exhibit a slight quiescent current decrease.

Input bias current increased significantly, but stayed within specification limits to 300 Krads(Si).

Positive and negative slew rate decreased as testing progressed to 300 Krads(Si). However, slew rate values stayed within pre-irradiation limits up to 150Krads(Si). Final slew rate was within post irradiation limits at 300 Krads(Si).

Transition times showed a slight increase, but stayed within pre-irradiation limits throughout testing.

MSK 106RH Biased/Unbiased Dose Rate Schedule

Dosimetry Equipment
Bruker Biospin # 0141

Irradiation Date
3/11/2010

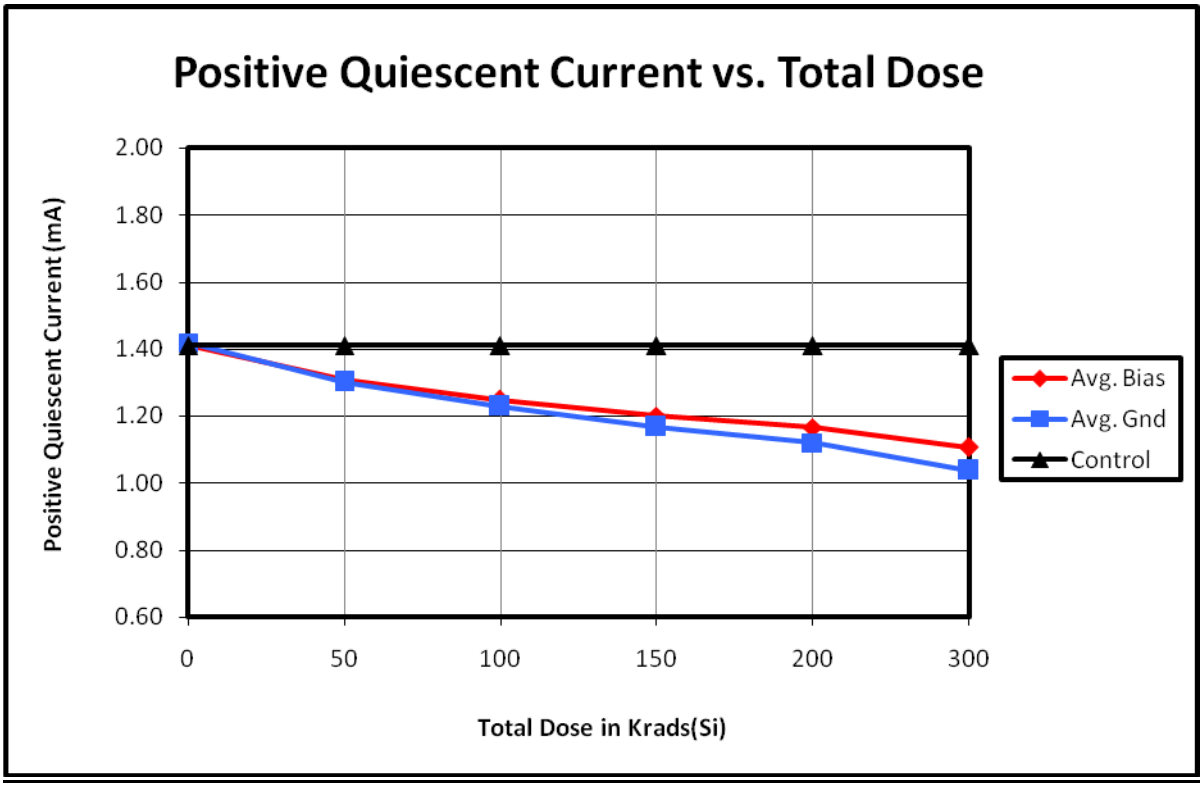
Exposure Length (min:sec)	Incremental Dose rads(Si)	Cumulative Dose rads(Si)
06:03	51,546	51,546
06:03	51,546	103,092
06:03	51,546	154,638
06:03	51,546	206,184
12:06	103,092	309,276

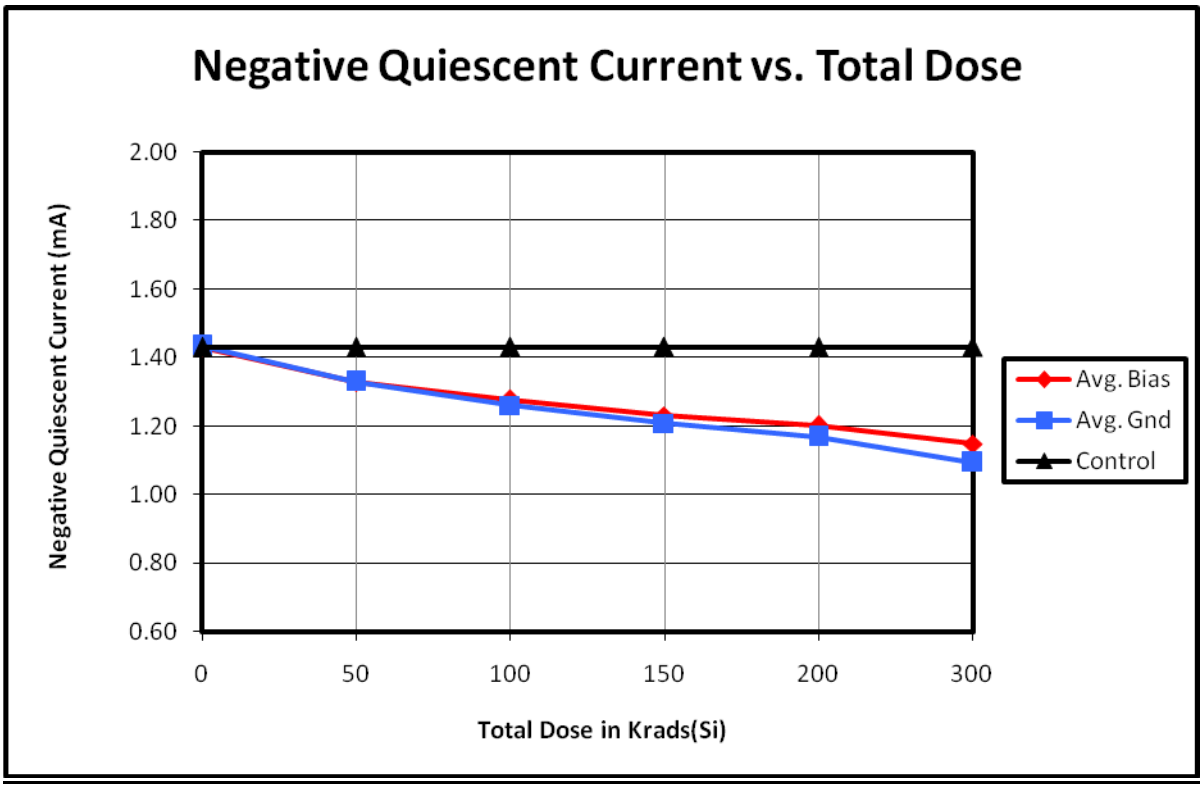
Biased S/N - 0263, 0624, 0265, 0267, 0268

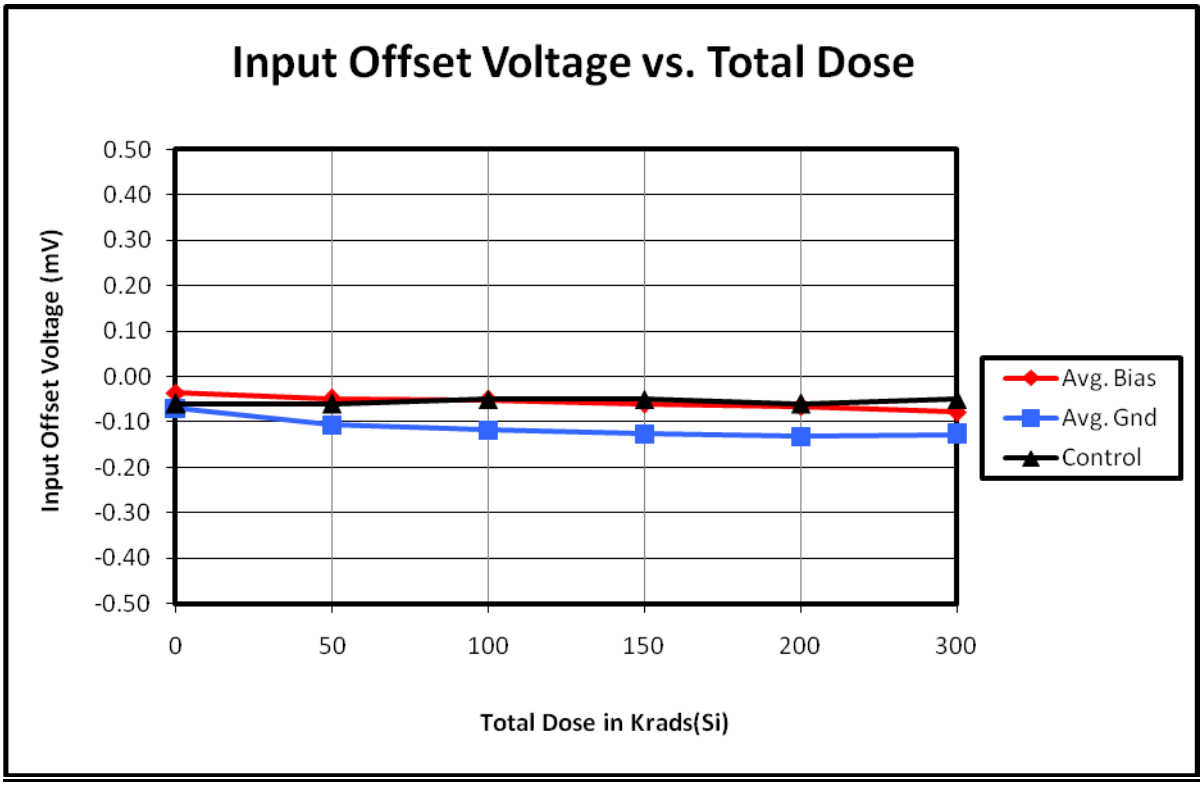
Unbiased S/N – 0269, 0270, 0271, 0272, 0274

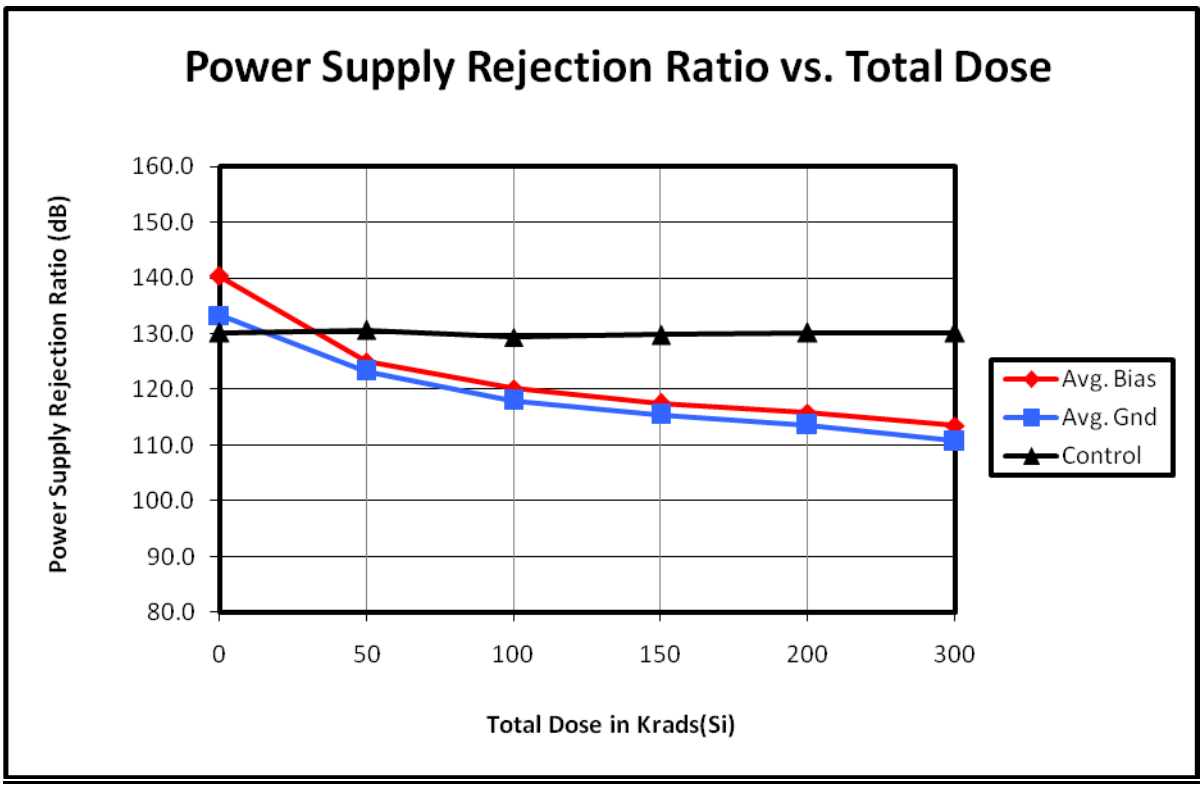
Table 1

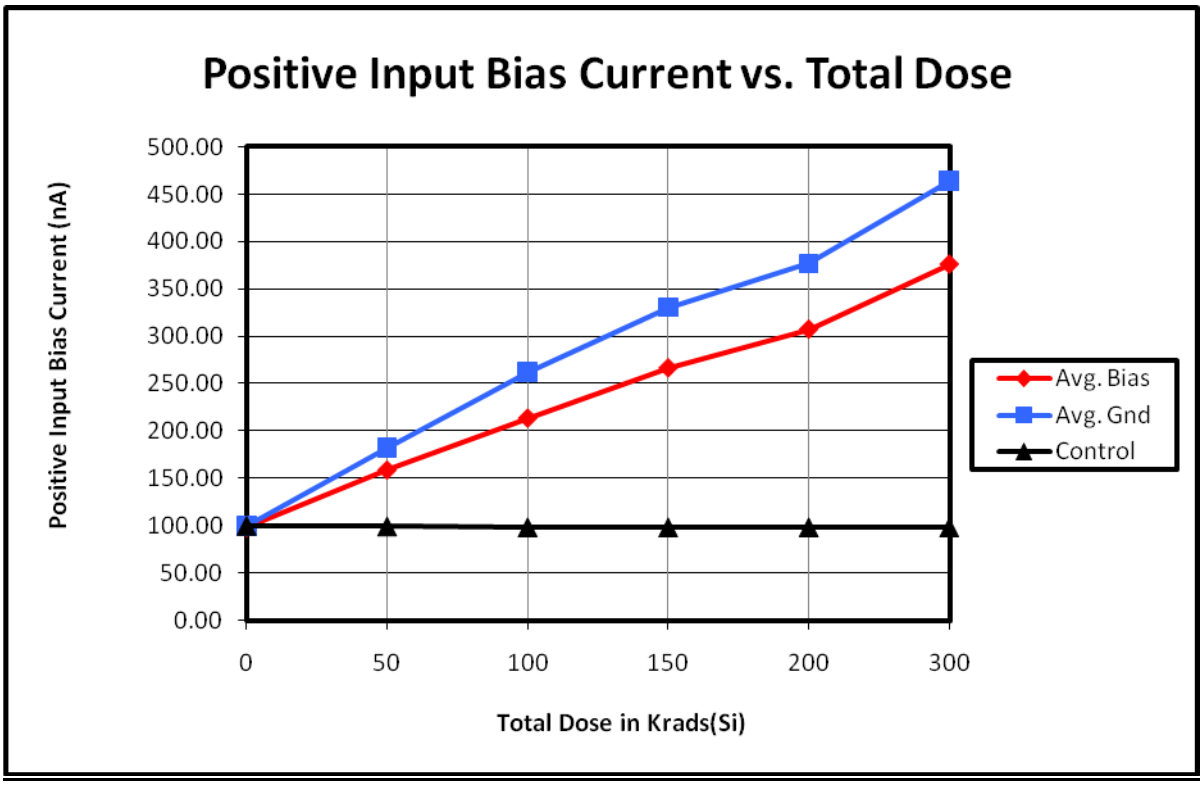
Dose Time, Incremental Dose and Total Cumulative Dose

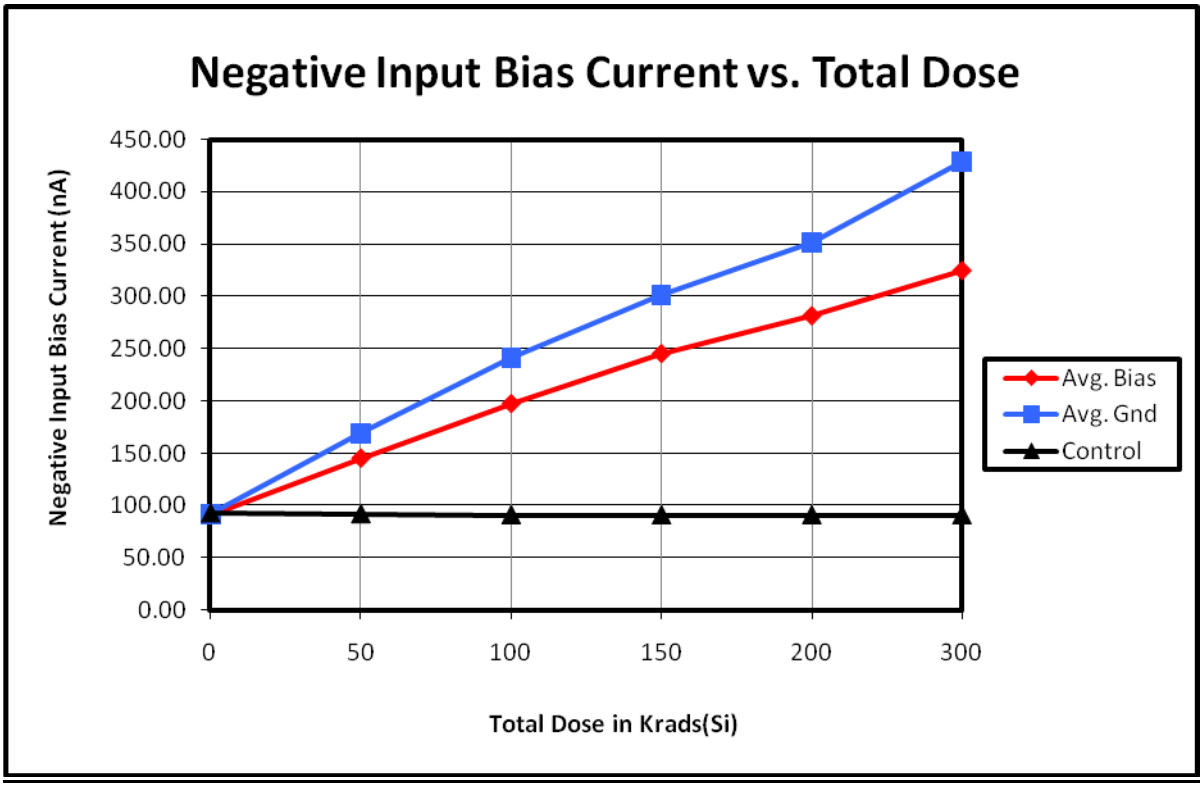

Positive Quiescent Current vs. Total Dose
Positive Quiescent Current (mA)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

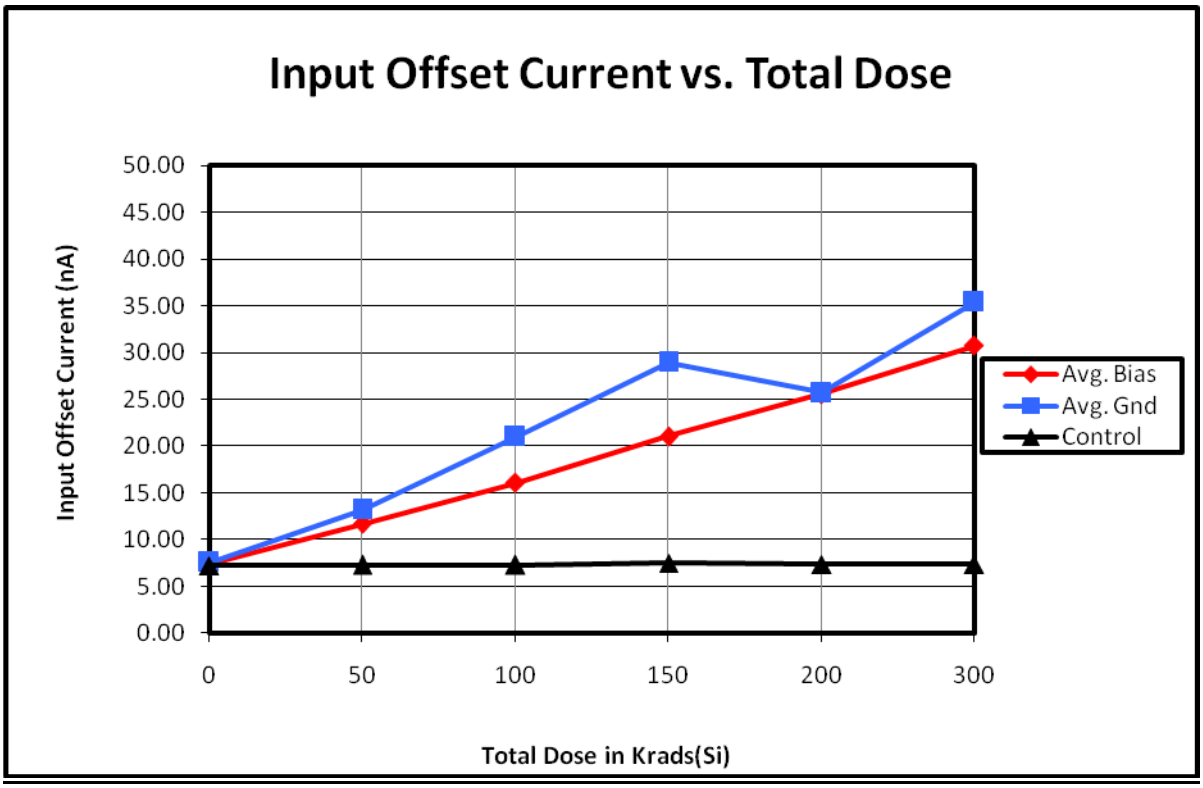

Negative Quiescent Current vs. Total Dose
Negative Quiescent Current (mA)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

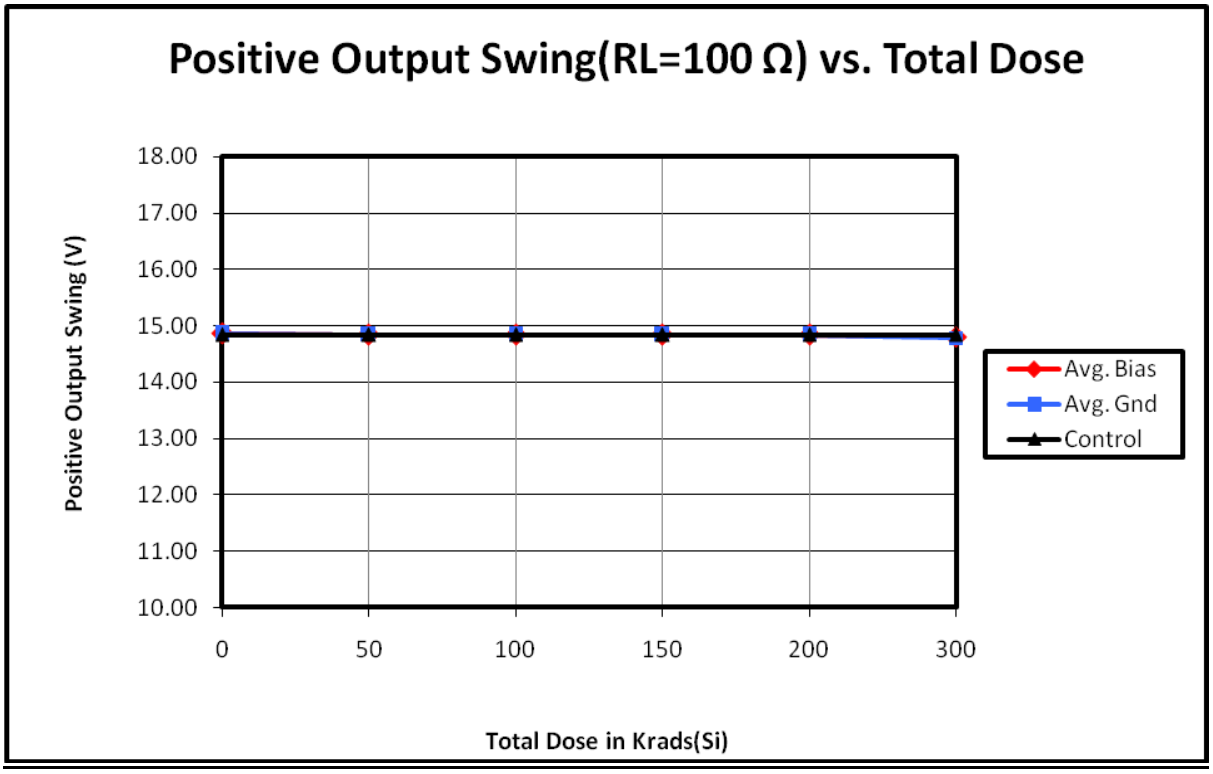

Input Offset Voltage vs. Total Dose
Input Offset Voltage (mV)
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

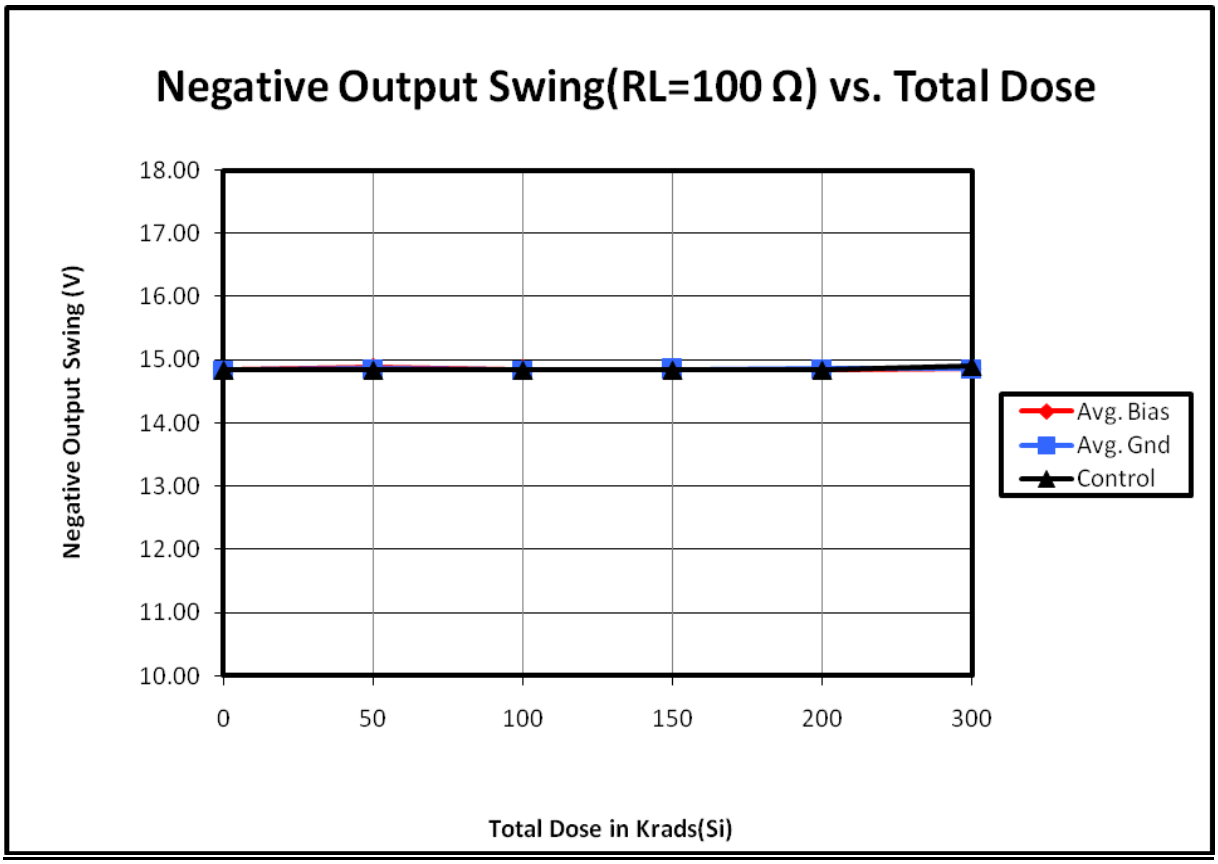

Power Supply Rejection Ratio vs. Total Dose
Power Supply Rejection Ratio (dB)
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

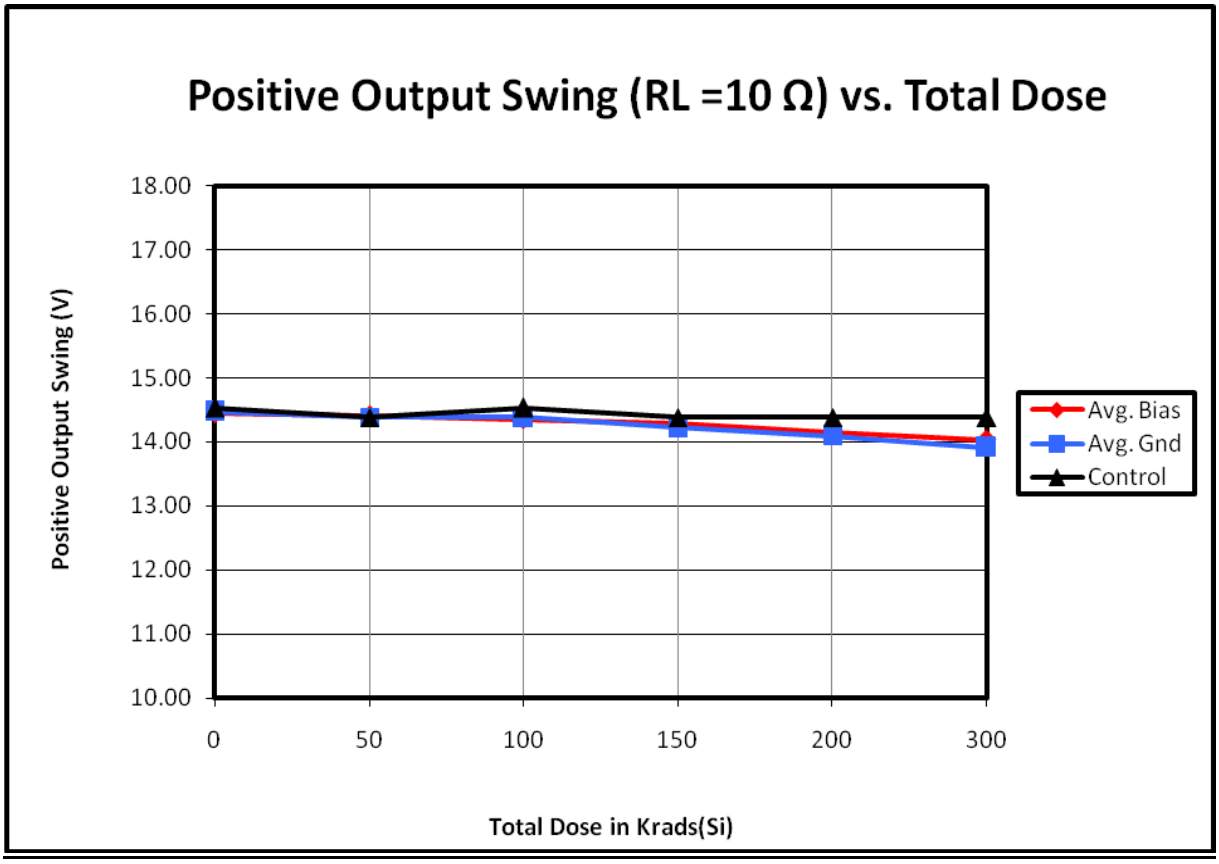

Positive Input Bias Current vs. Total Dose
Positive Input Bias Current (nA)
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

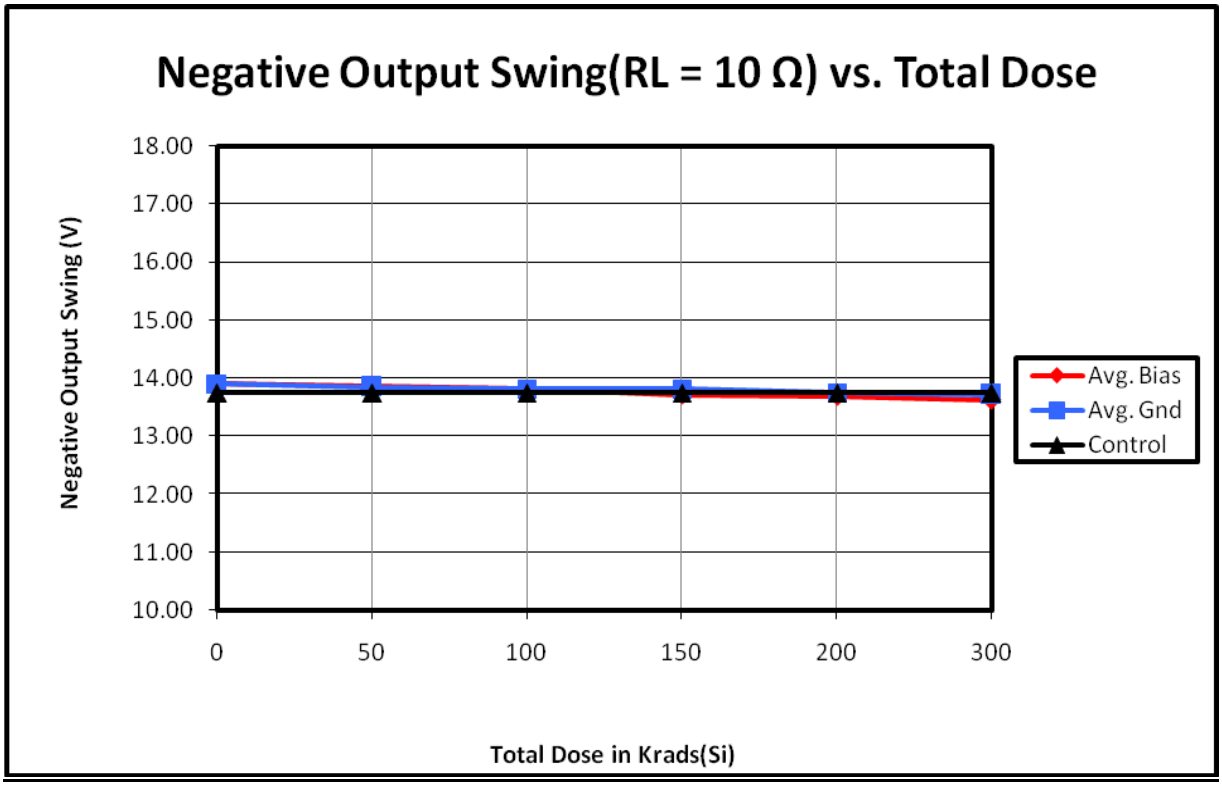

Negative Input Bias Current vs. Total Dose
Negative Input Bias Current (nA)
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

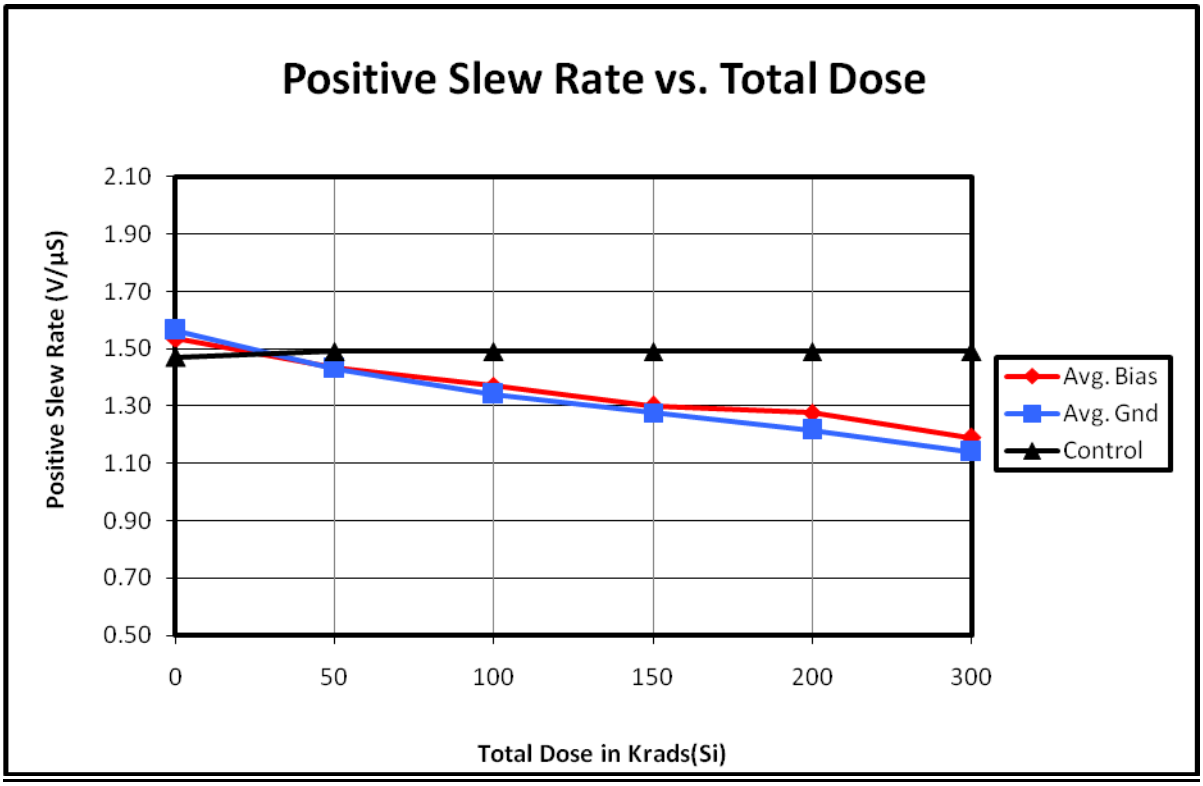

Input Offset Current vs. Total Dose
Input Offset Current (nA)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

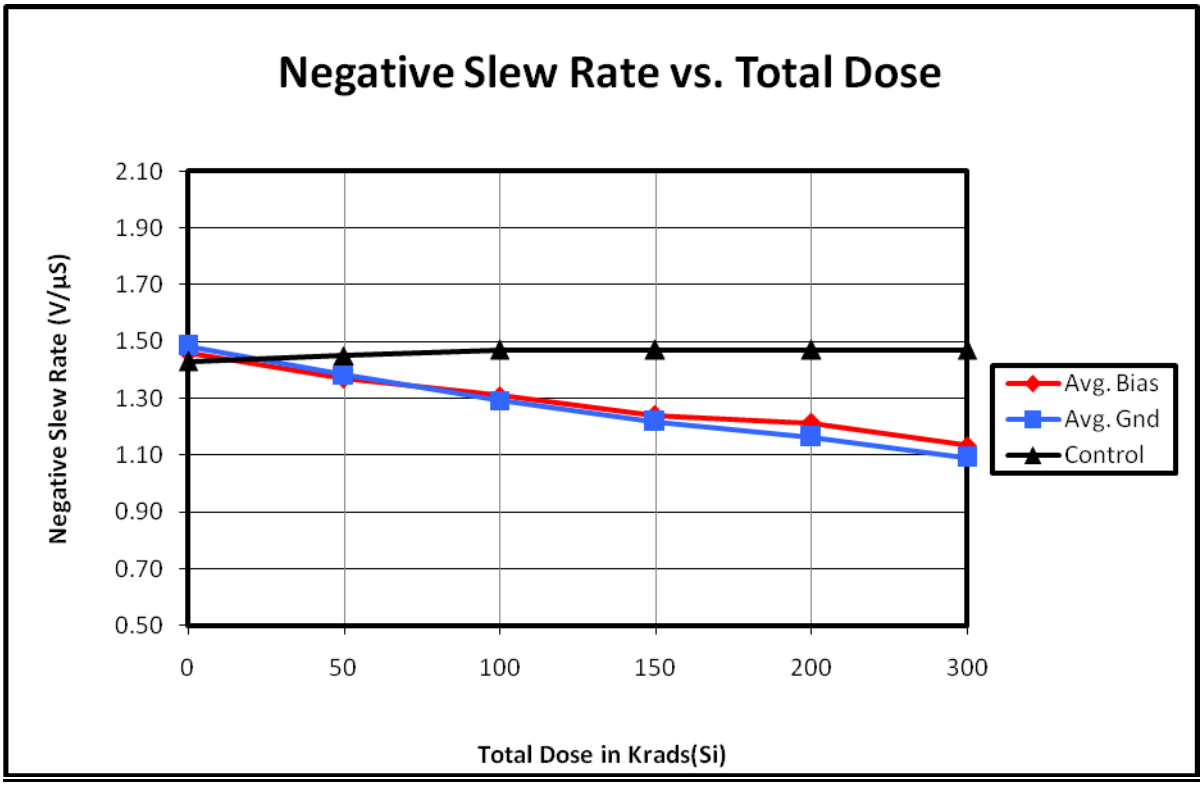

Positive Output Swing(RL=100 Ω) vs. Total Dose
Positive Output Swing (V)
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

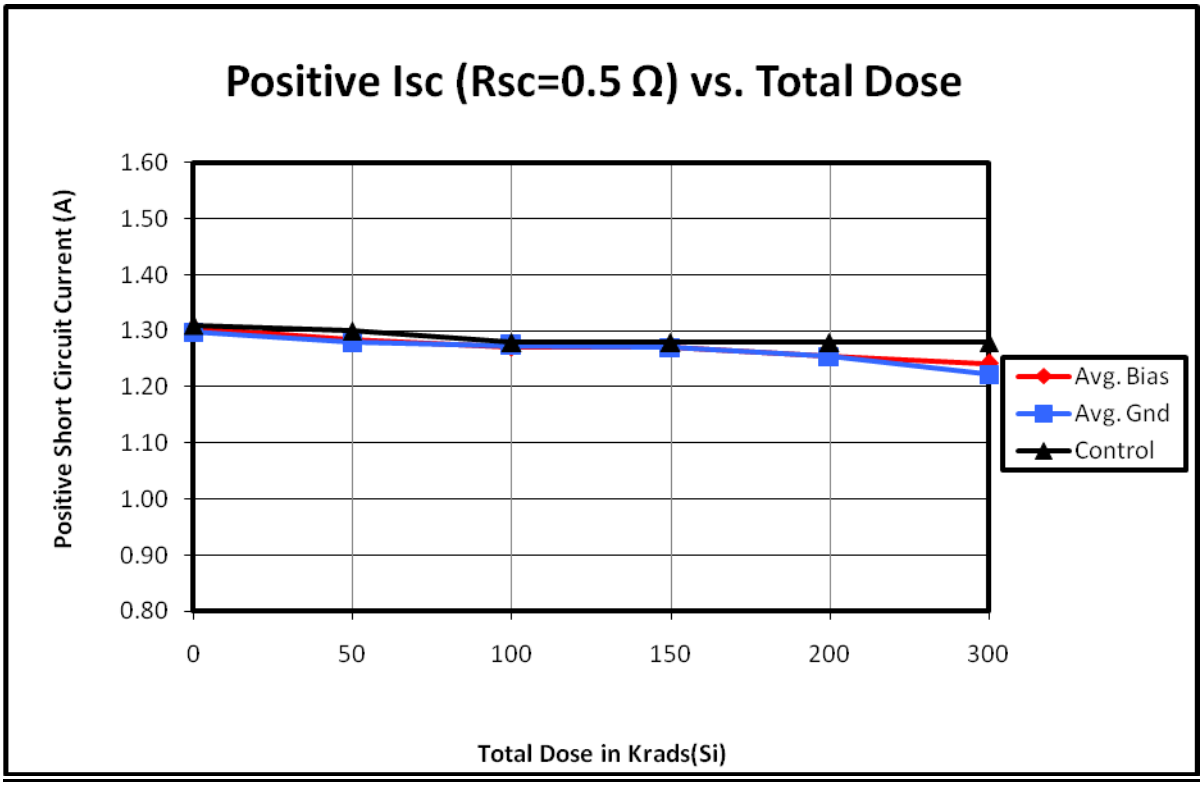

Negative Output Swing(RL=100 Ω) vs. Total Dose
Negative Output Swing (V)
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
0
50
100
150
200
300
Avg. Bias
Avg. Gnd
Control
Total Dose in Krads(Si)

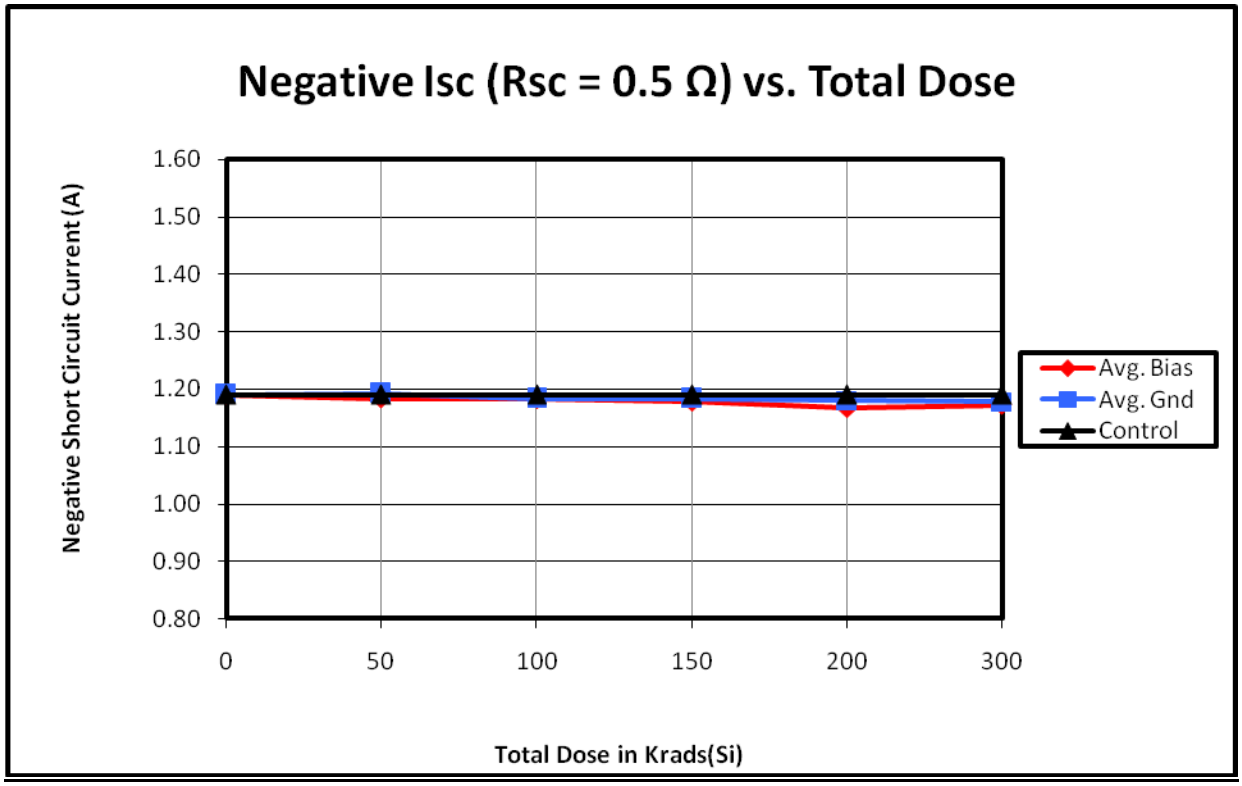

Positive Output Swing (RL =10 Ω) vs. Total Dose
Positive Output Swing (V)
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
0
50
100
150
200
300
Avg. Bias
Avg. Gnd
Control
Total Dose in Krads(Si)

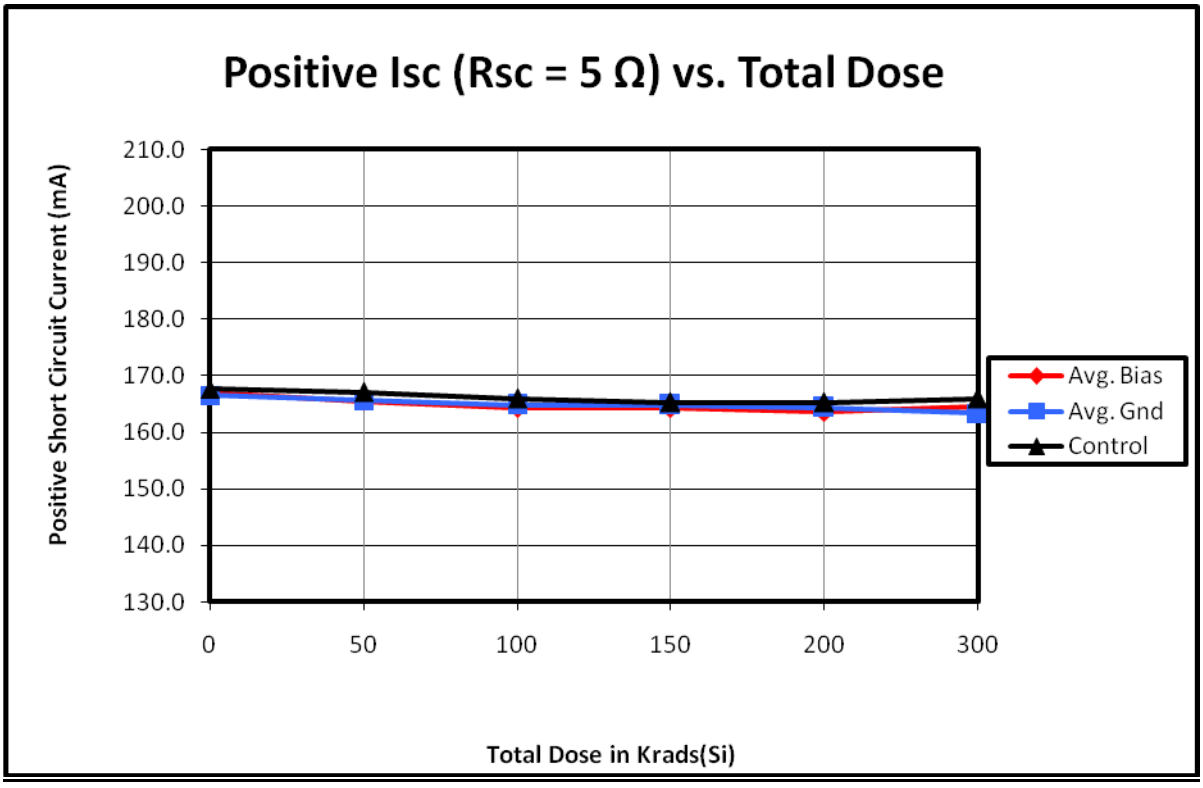

Negative Output Swing(RL = 10 Ω) vs. Total Dose
Negative Output Swing (V)
18.00
17.00
16.00
15.00
14.00
13.00
12.00
11.00
10.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

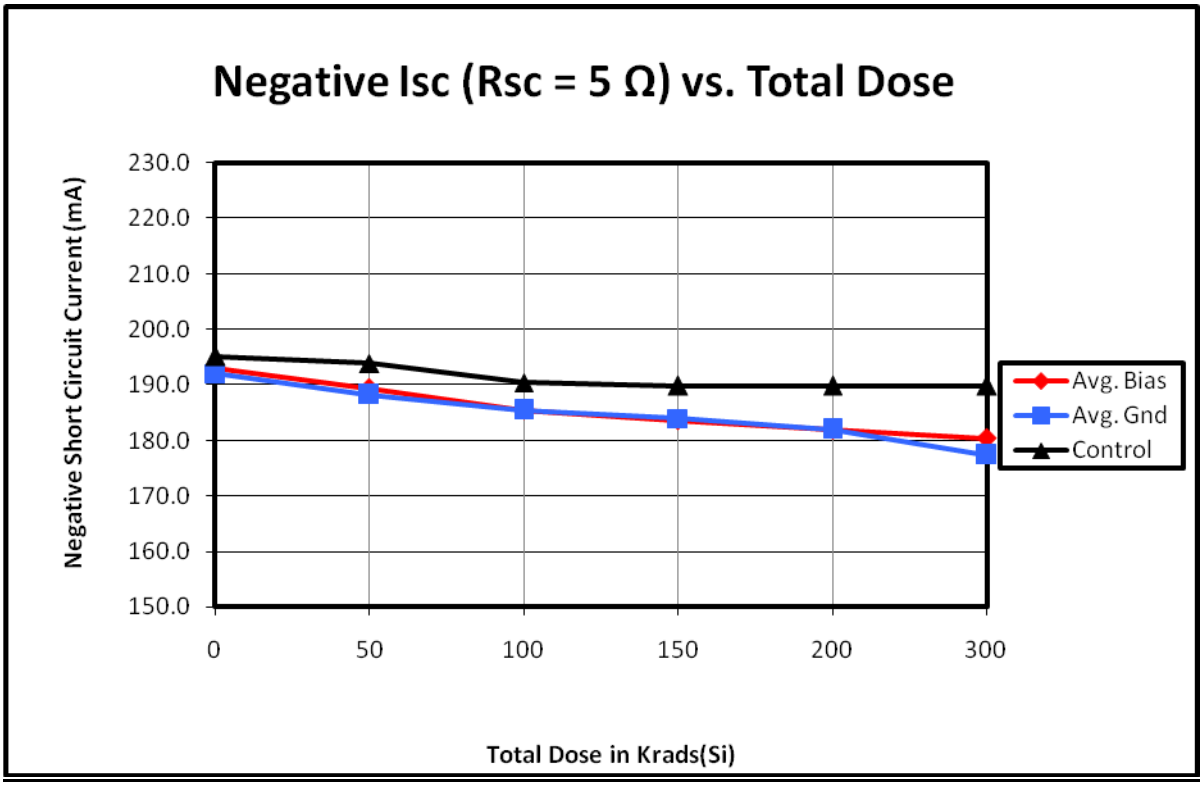

Positive Slew Rate vs. Total Dose
Positive Slew Rate (V/µS)
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

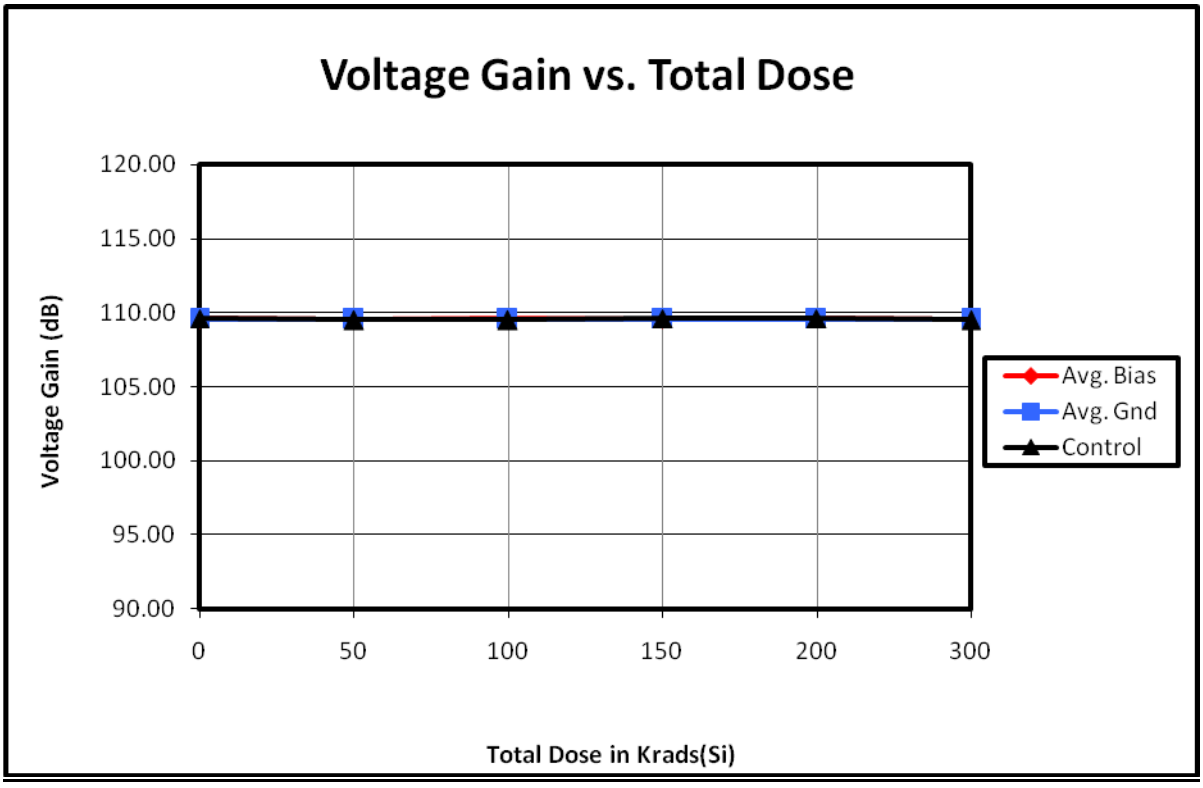

Negative Slew Rate vs. Total Dose
Negative Slew Rate (V/µS)
2.10
1.90
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

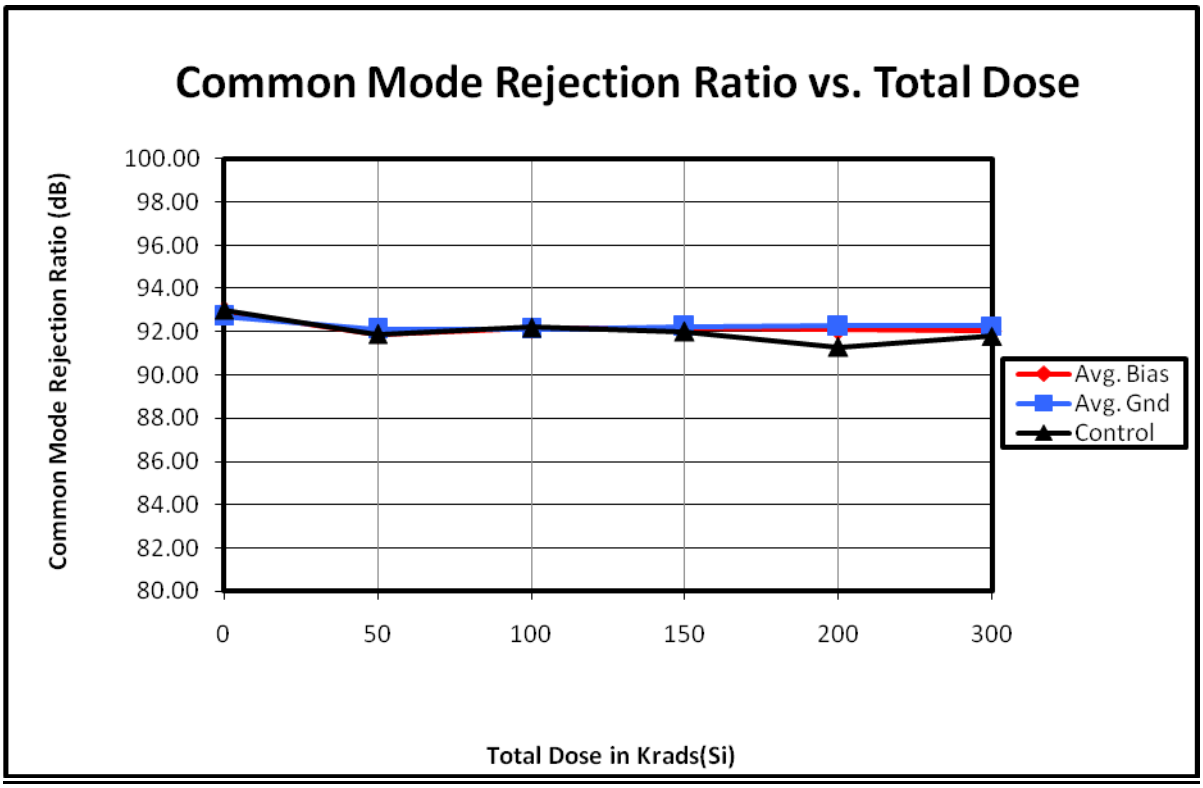

Positive Isc (Rsc=0.5 Ω) vs. Total Dose
Positive Short Circuit Current (A)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

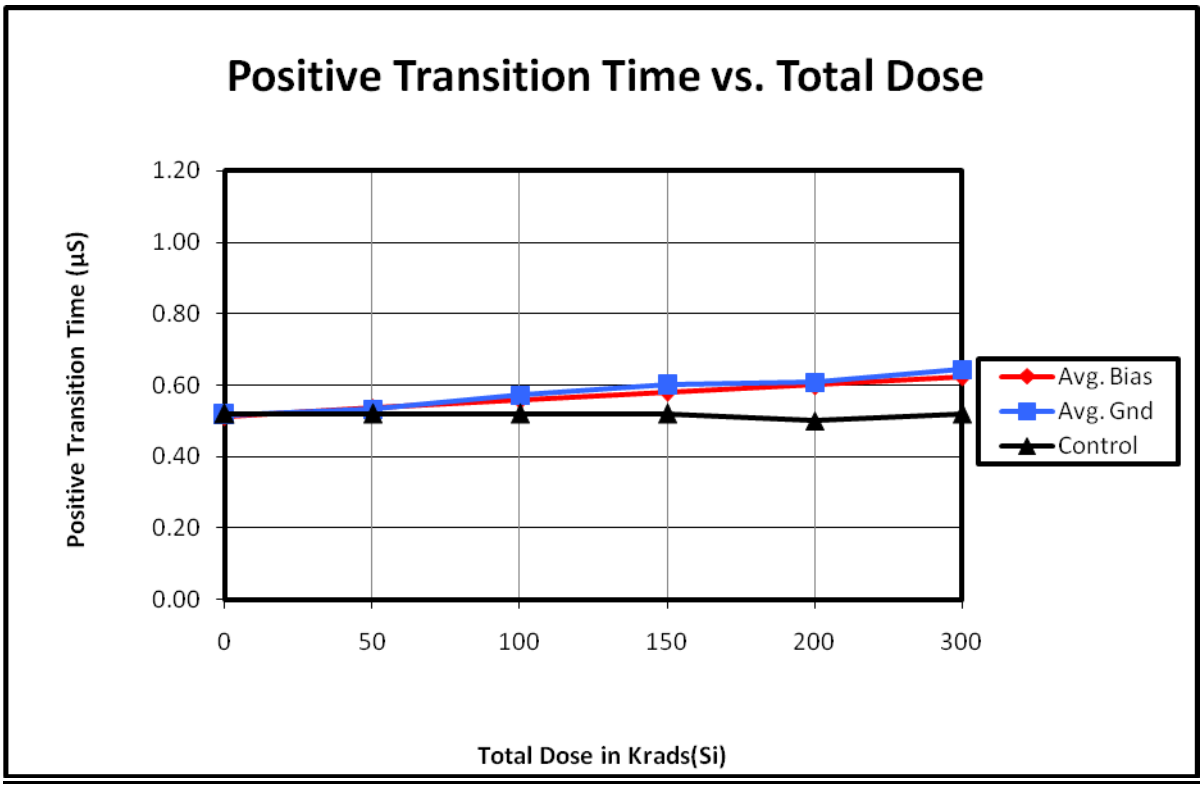

Negative Isc (Rsc = 0.5 Ω) vs. Total Dose
Negative Short Circuit Current (A)
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

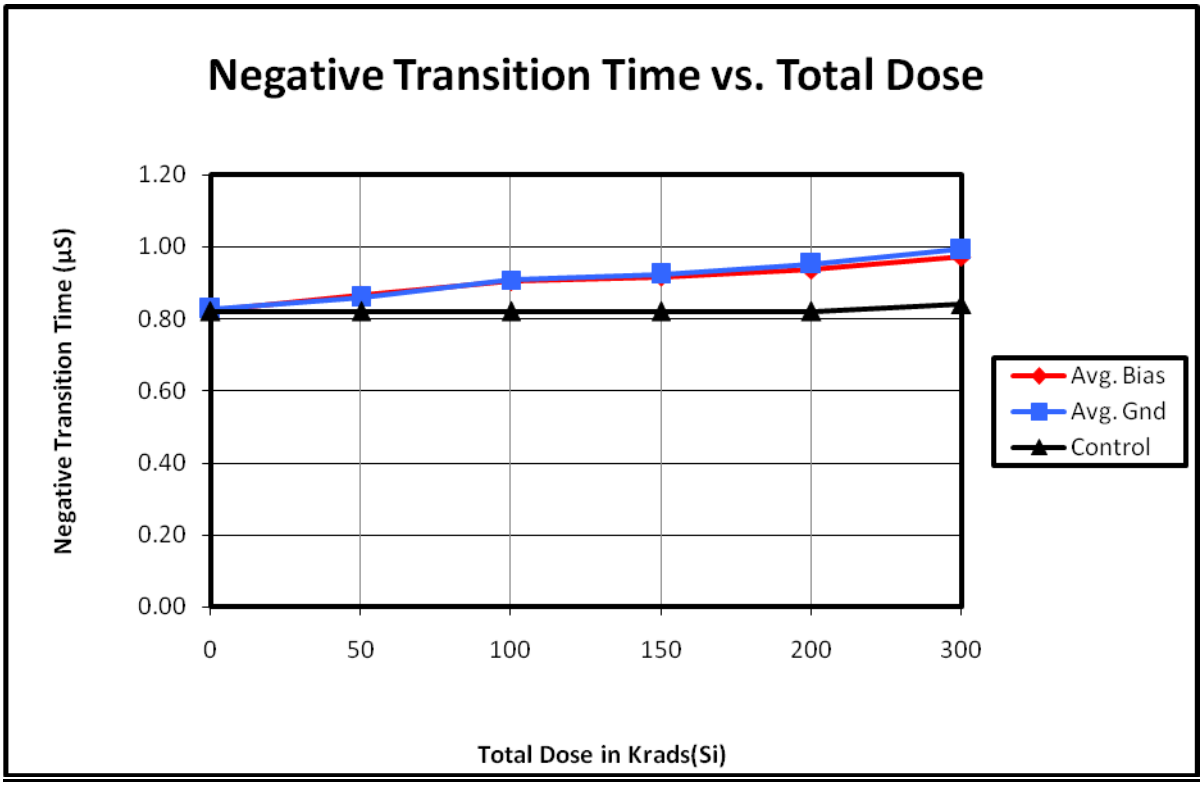

Positive Isc (Rsc = 5 Ω) vs. Total Dose
Positive Short Circuit Current (mA)
210.0
200.0
190.0
180.0
170.0
160.0
150.0
140.0
130.0
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

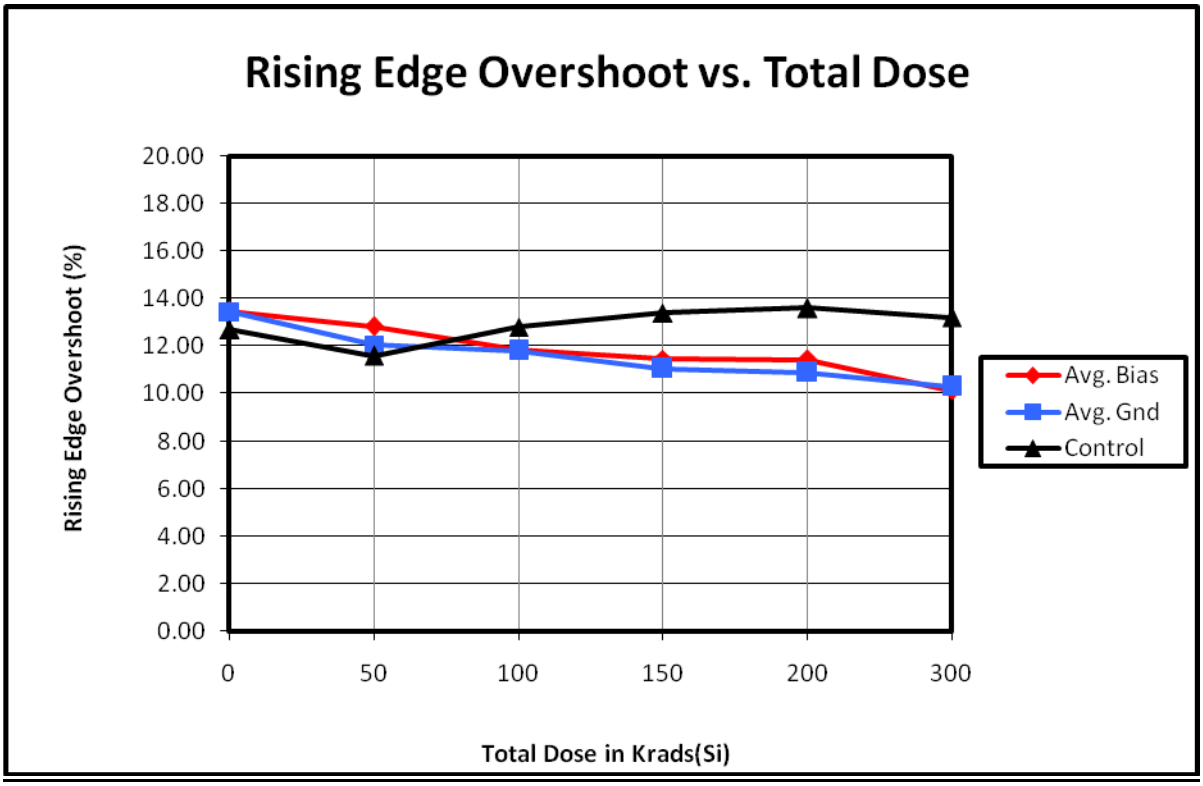

Negative Isc (Rsc = 5 Ω) vs. Total Dose
Negative Short Circuit Current (mA)
230.0
220.0
210.0
200.0
190.0
180.0
170.0
160.0
150.0
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

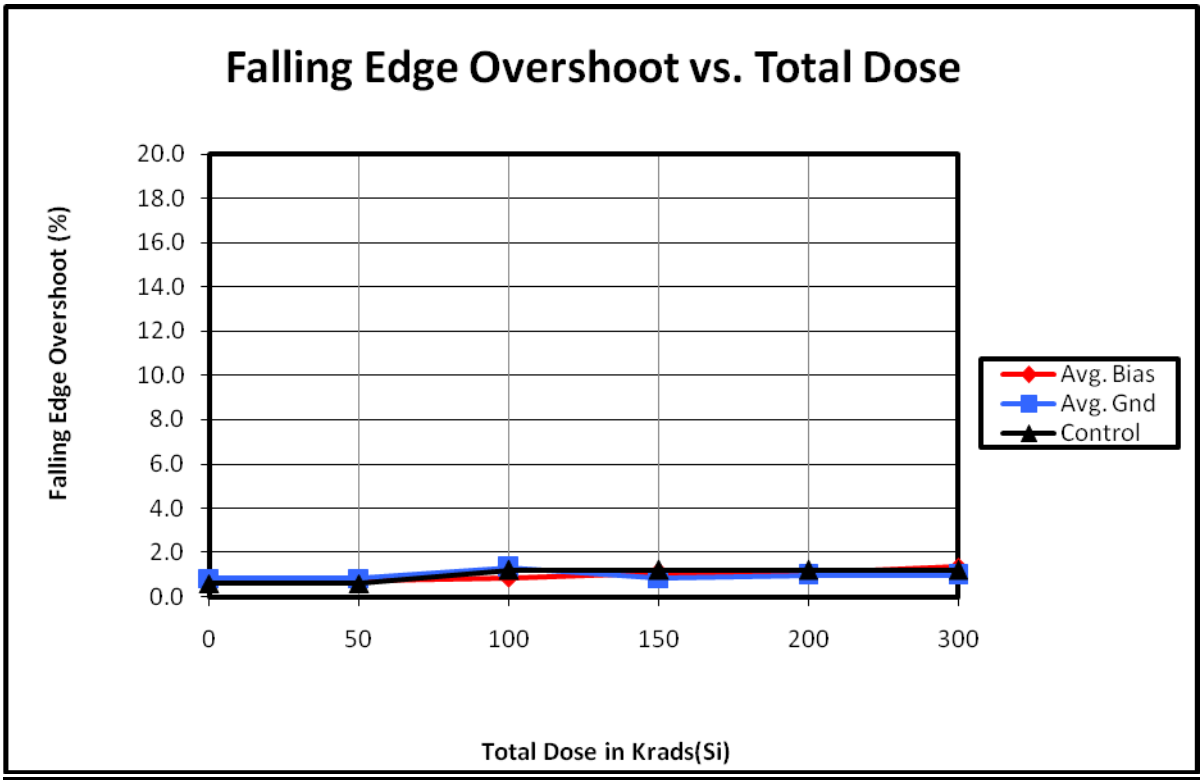

Voltage Gain vs. Total Dose
Voltage Gain (dB)
120.00
115.00
110.00
105.00
100.00
95.00
90.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Common Mode Rejection Ratio vs. Total Dose
Common Mode Rejection Ratio (dB)
100.00
98.00
96.00
94.00
92.00
90.00
88.00
86.00
84.00
82.00
80.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Positive Transition Time vs. Total Dose
Positive Transition Time (µS)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Negative Transition Time vs. Total Dose
Negative Transition Time (µS)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Rising Edge Overshoot vs. Total Dose
Rising Edge Overshoot (%)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Falling Edge Overshoot vs. Total Dose
Falling Edge Overshoot (%)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

Total Dose Radiation Test Report

MSK 106RH

Radiation Hardened High Power Op Amp

January 3, 2005
Updated on August 4, 2006
Updated on January 25, 2008 (Second Test)

J. Douglas
P. Musil

M.S. Kennedy Corporation
Liverpool, NY

I. Introduction:

The total dose radiation test plan for the MSK 106RH was developed to qualify the device as radiation hardened up to 100 Krad(Si). The testing was performed beyond 100 Krad(Si) to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the hybrid, but simply offers designers insight to the critical parameter-shifts beyond the specified total dose level.

MIL-STD-883 Method 1019.7 and ASTM F1892-06 were used as guidelines in the development and implementation of the total dose test plan for the MSK 106RH.

II. Radiation Source:

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. Dosimetry was performed prior to device irradiation and the dose rate was determined to be 102 rads(Si)/sec. The total dose schedule can be found in Table I.

III. Test Setup:

All test samples were subjected to Group A Electrical Test in accordance with the device data sheet. In addition, all devices received 320 hours of burn-in per MIL-STD-883 Method 1015 and were electrically tested prior to irradiation. For test platform verification, one control device was tested at 25°C.

The devices were vertically aligned with the radiation source and enclosed in a Pb/Al container during irradiation to minimize dose enhancement effects. Five devices were kept under bias during irradiation. Five devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and were transported to the MSK automatic electrical test platform and tested IAW MSK device data sheet. Testing was performed on irradiated devices, as well as the control device, at each total dose level. Electrical tests were completed within one hour of irradiation.

IV. Data:

All performance curves are averaged from the test results of the biased and unbiased devices respectively.

V. Summary:

The devices performed well with respect to TID. Devices exhibited a slight quiescent current decrease.

Input bias current increased significantly, but stayed within specification limits to 300 Krads(Si).

Positive and negative slew rate decreased as testing progressed to 300 Krads(Si). However, slew rate values stayed within pre-irradiation limits up to 150Krads(Si). Final slew rate was within post irradiation limits at 300 Krads(Si).

Transition times showed a slight increase, but stayed within pre-irradiation limits throughout testing.

MSK 106RH Biased/Unbiased Dose Rate Schedule

Dosimetry Equipment
Bruker Biospin # 0141

Irradiation Date
1/10/2008

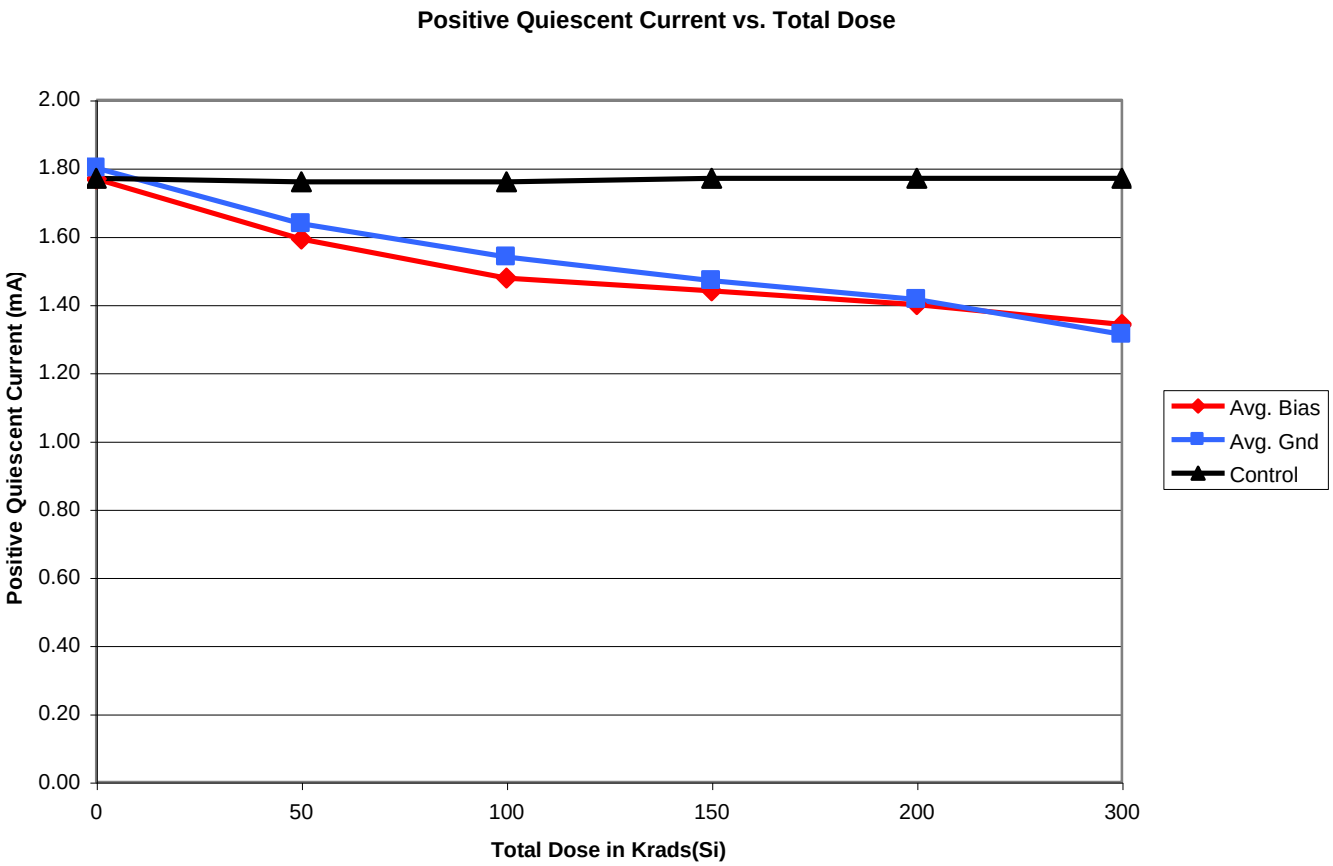
Exposure Length (min:sec)	Incremental Dose rads(Si)	Cumulative Dose rads(Si)
8:25	51,510	51,510
8:25	51,510	103,020
8:25	51,510	154,530
8:25	51,510	206,040
16:50	103,020	309,060

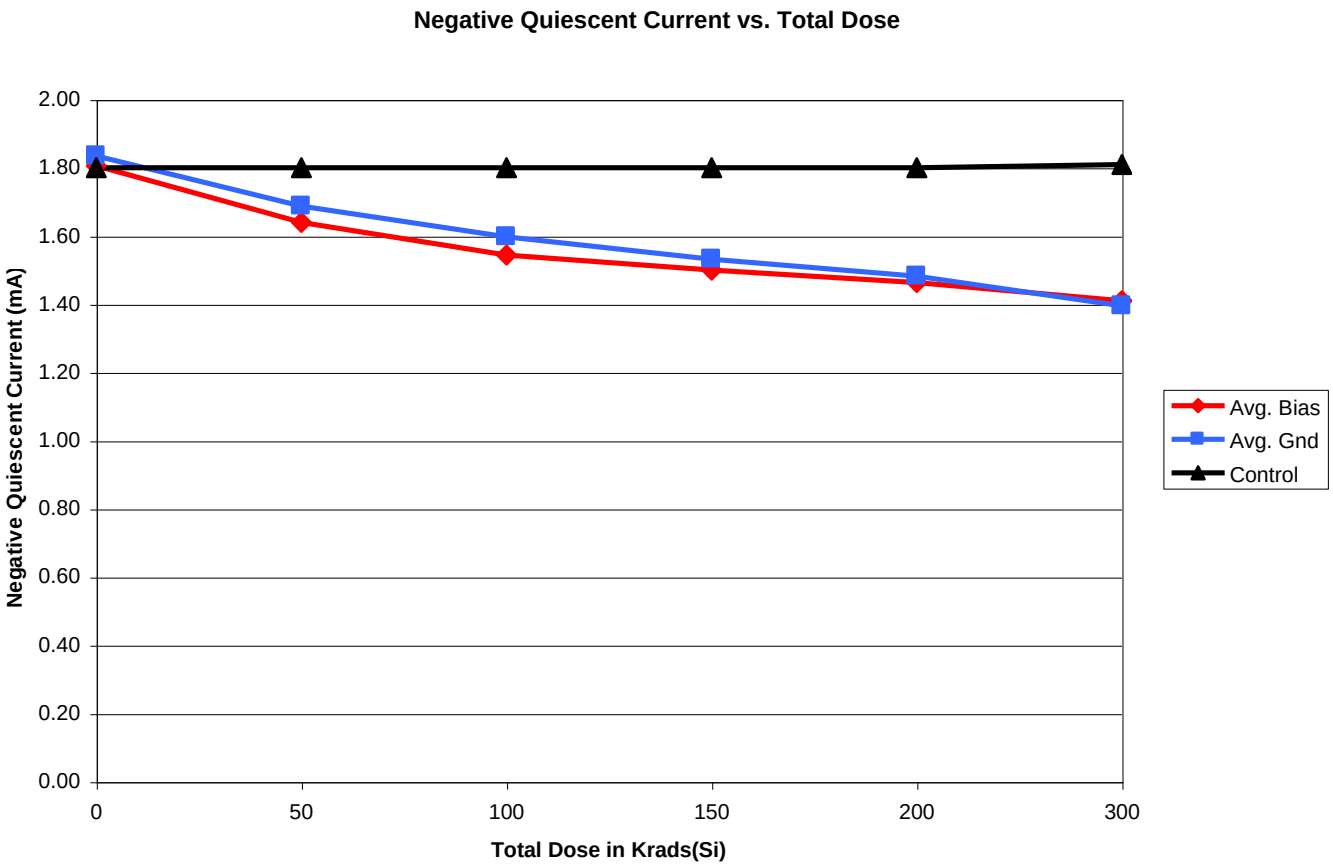
Biased S/N - 0161, 0162, 0163, 0164, 0165

Unbiased S/N - 0148, 0157, 0158, 0159, 0160

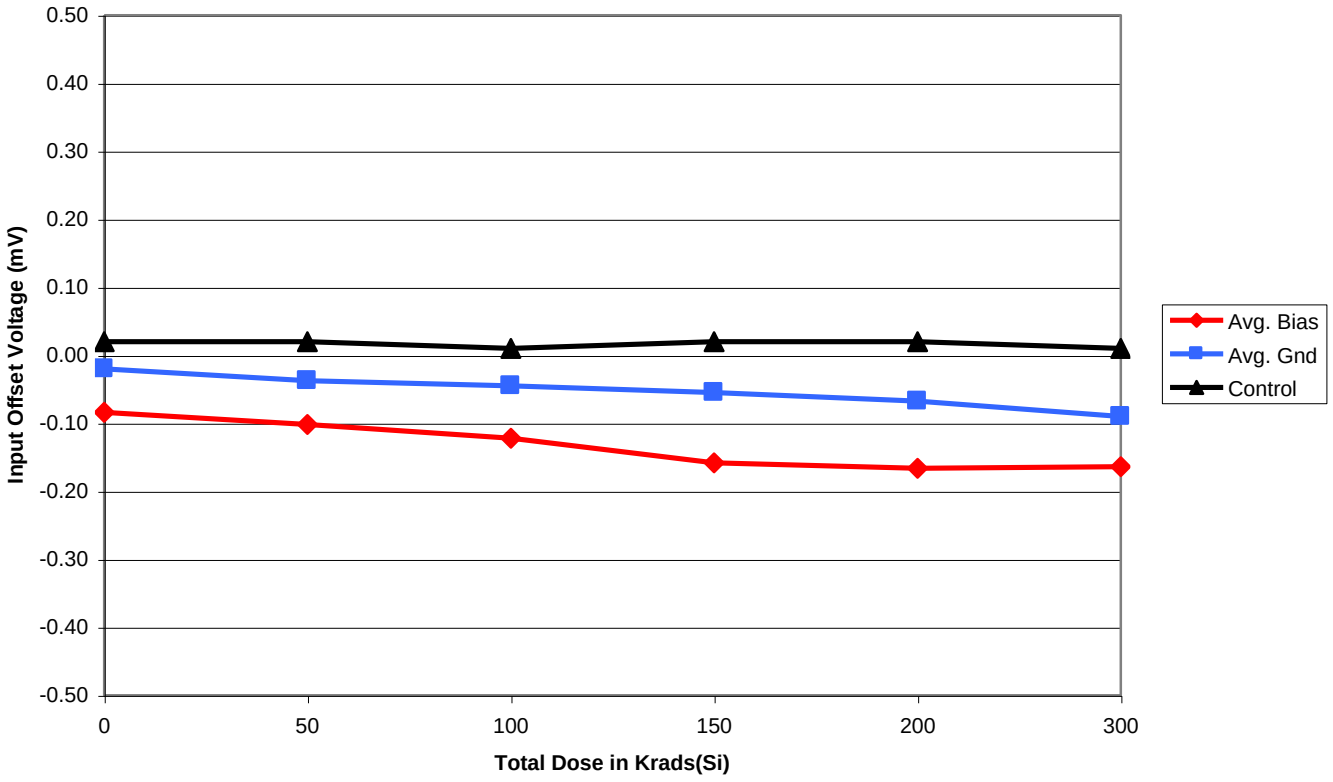
Table 1

Dose Time, Incremental Dose and Total Cumulative Dose

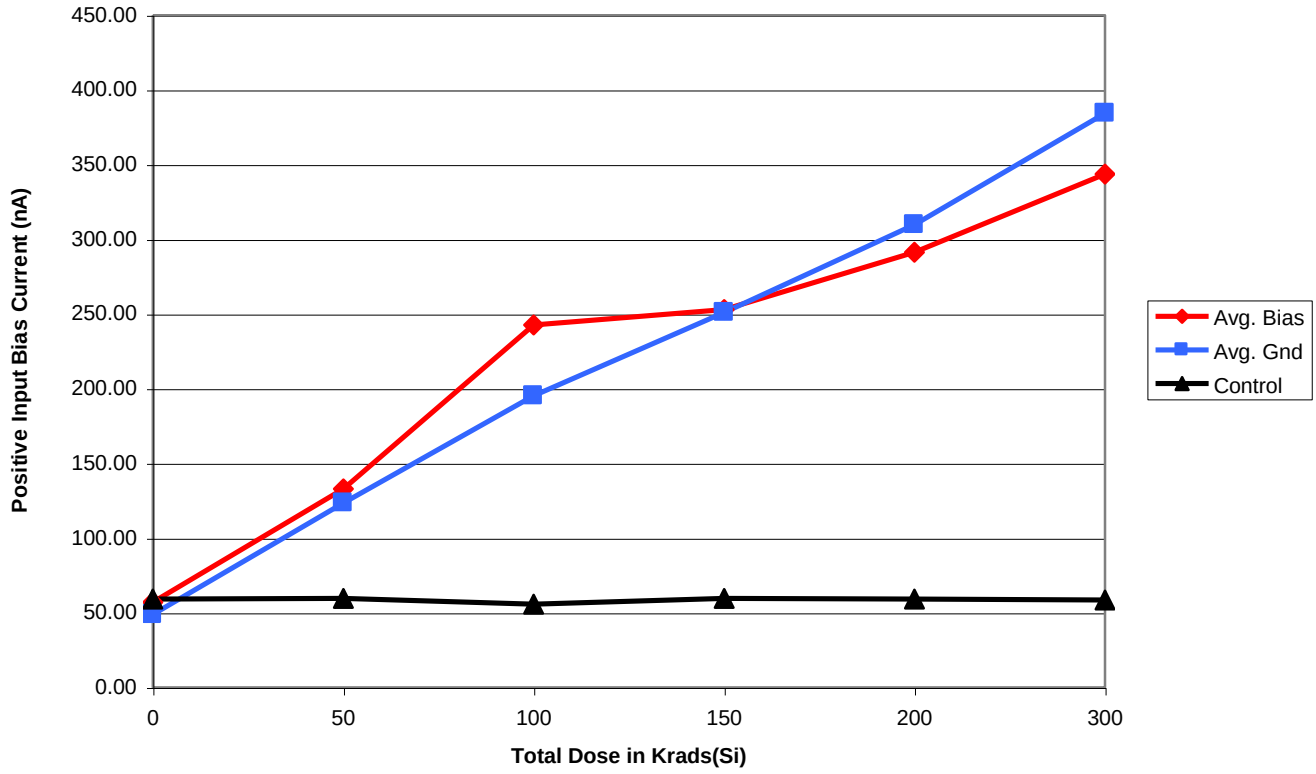

Positive Quiescent Current vs. Total Dose
Positive Quiescent Current (mA)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Negative Quiescent Current vs. Total Dose
Negative Quiescent Current (mA)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

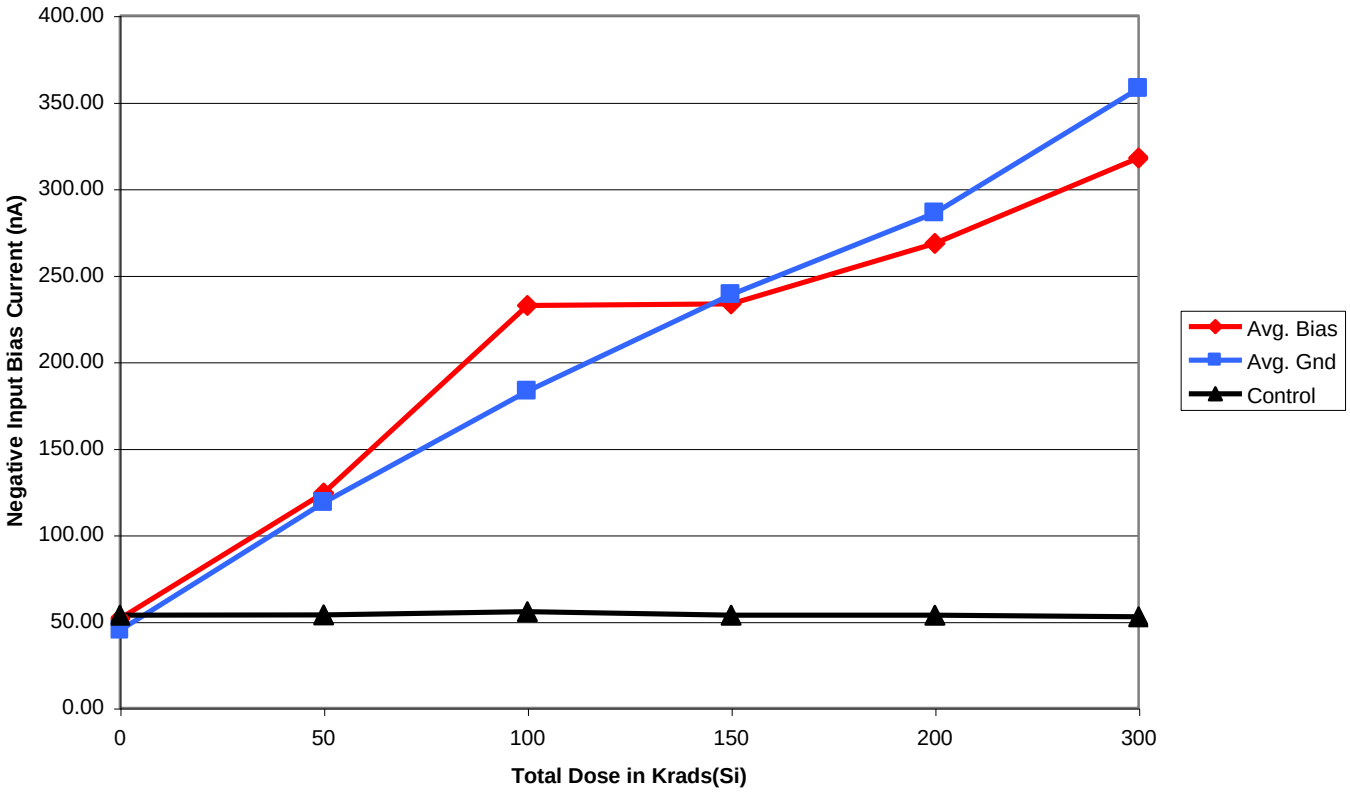
Input Offset Voltage vs. Total Dose



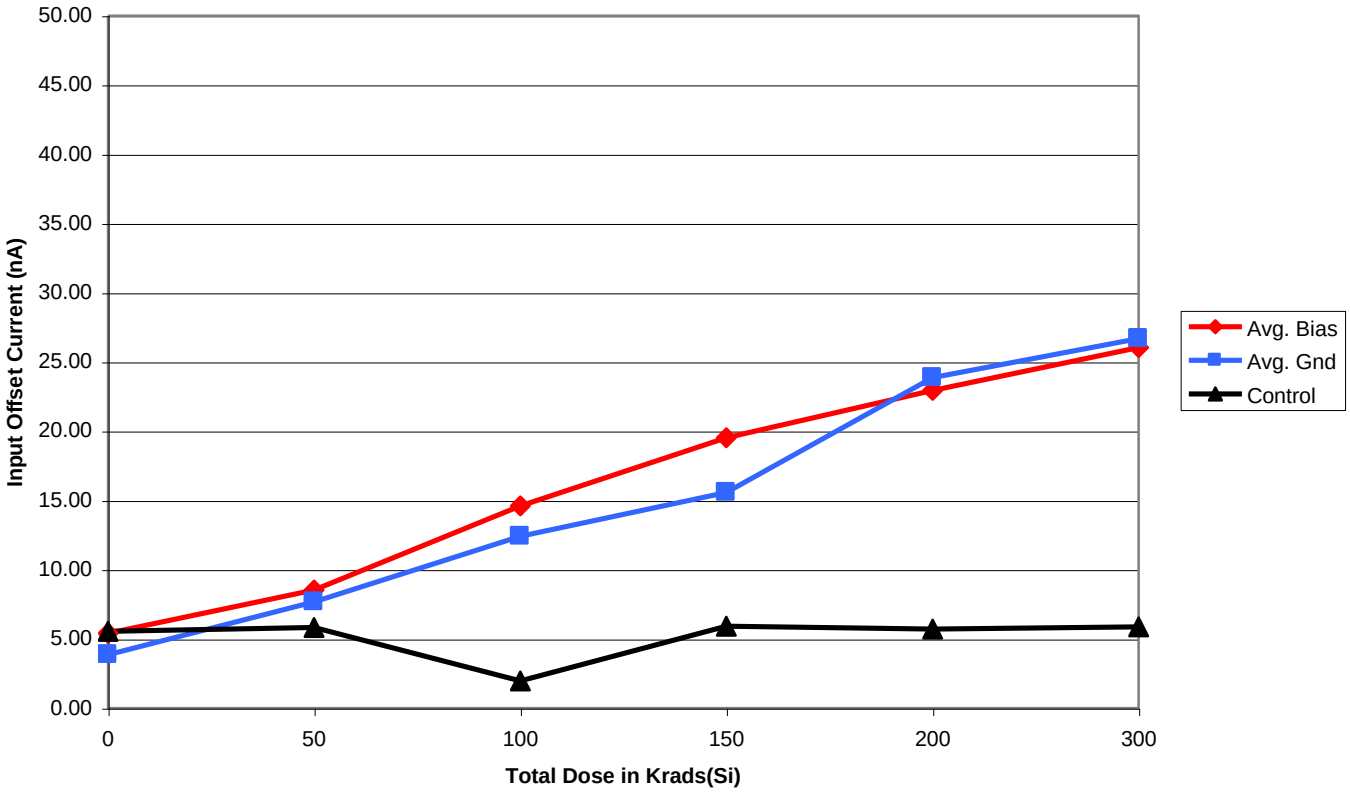
Positive Input Bias Current vs. Total Dose

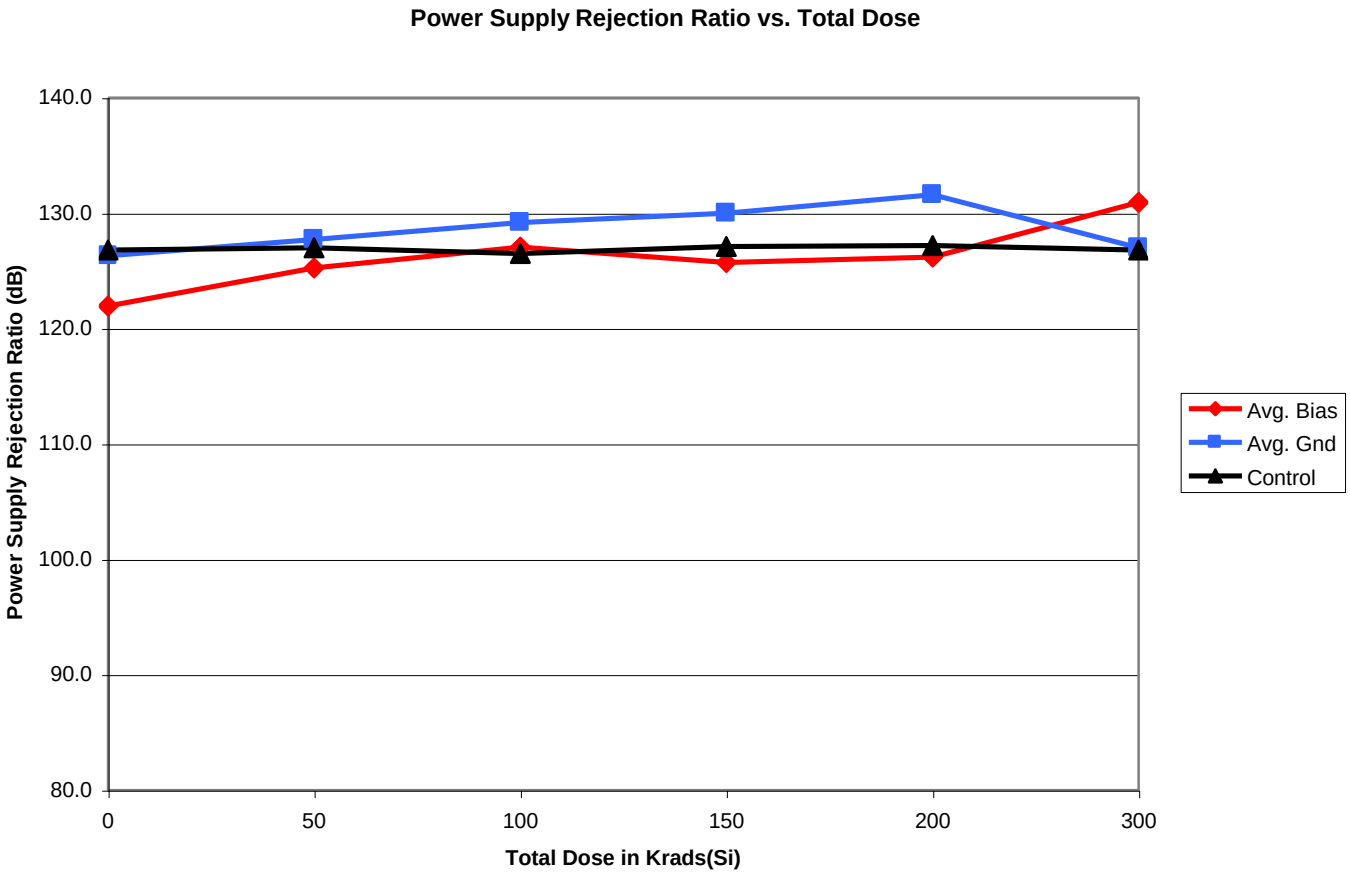


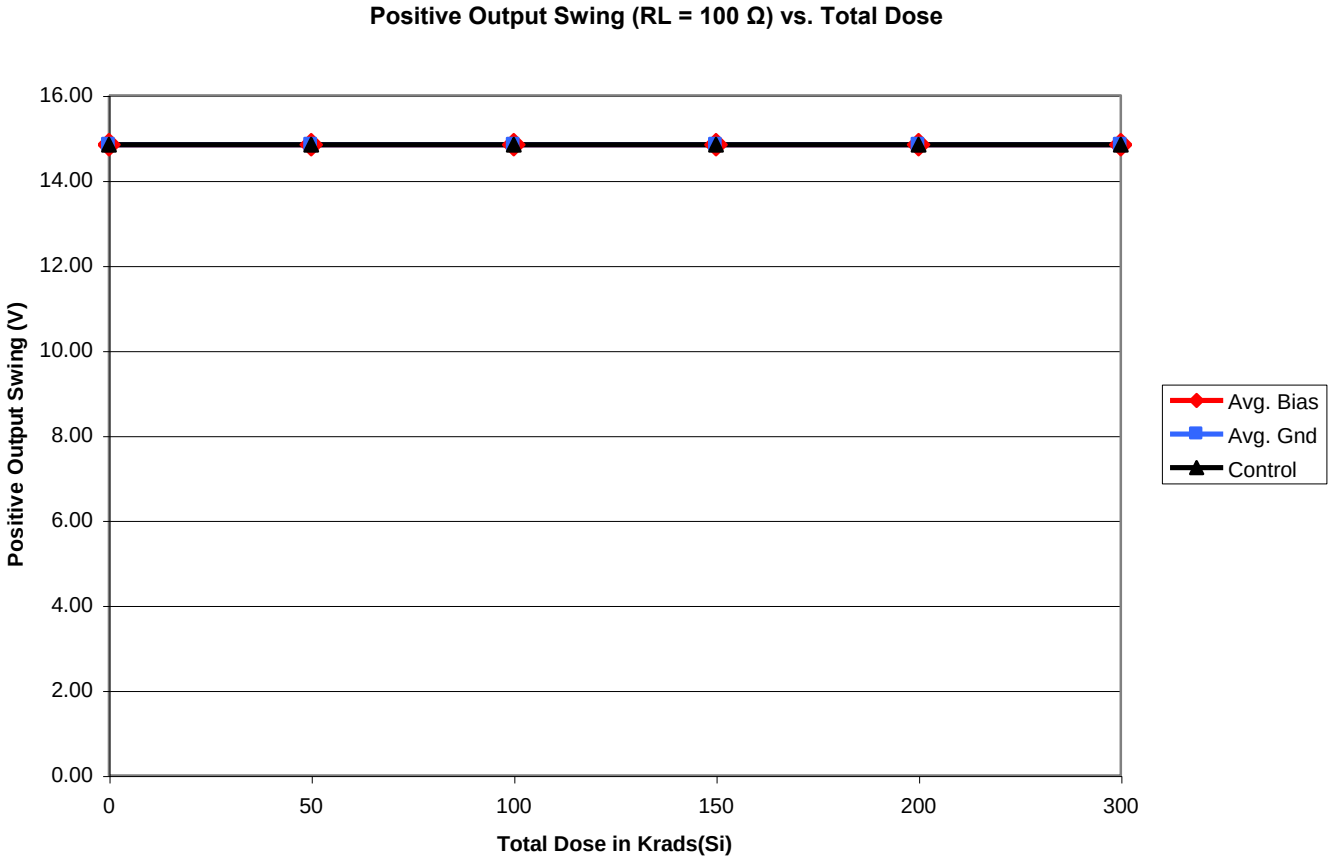
Negative Input Bias Current vs. Total Dose

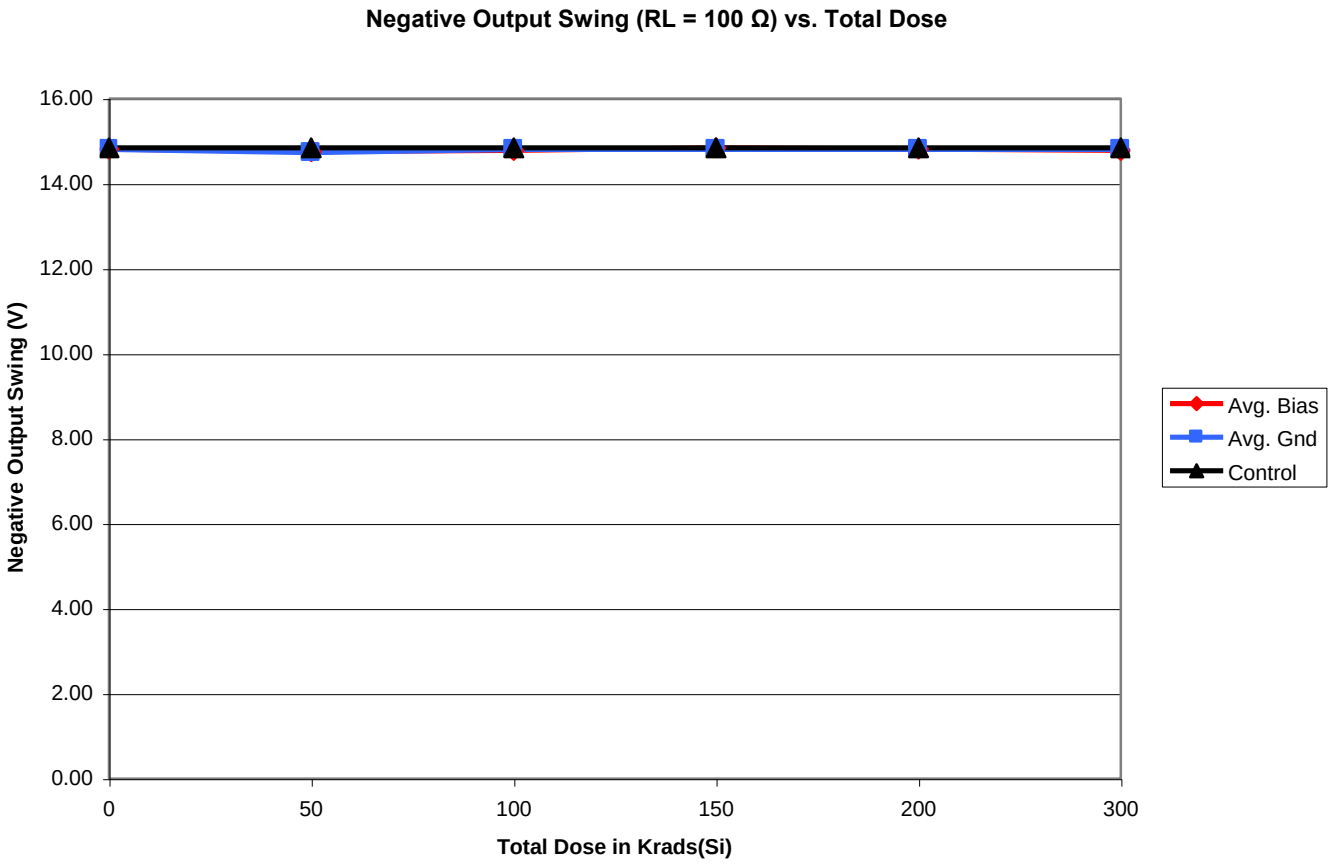


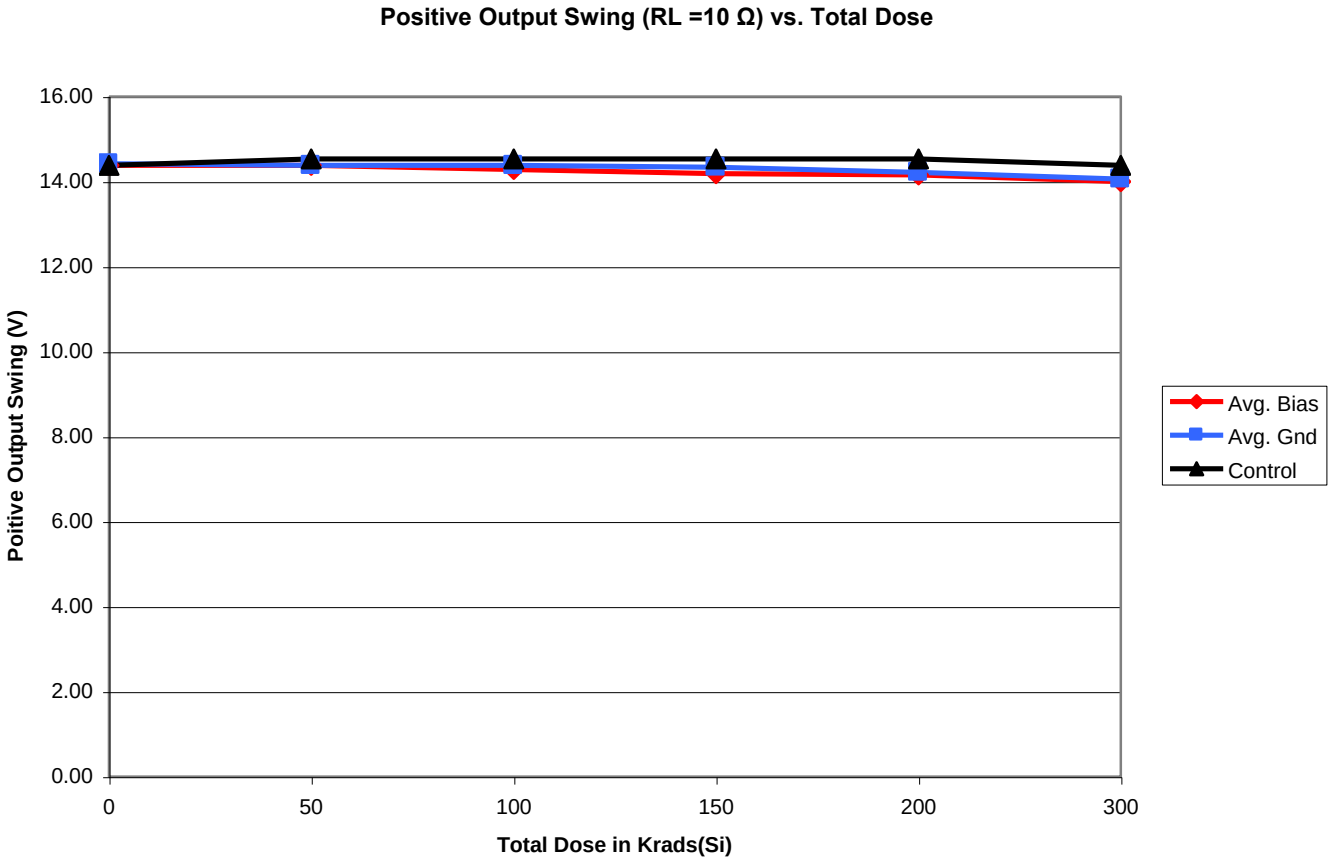
Input Offset Current vs. Total Dose

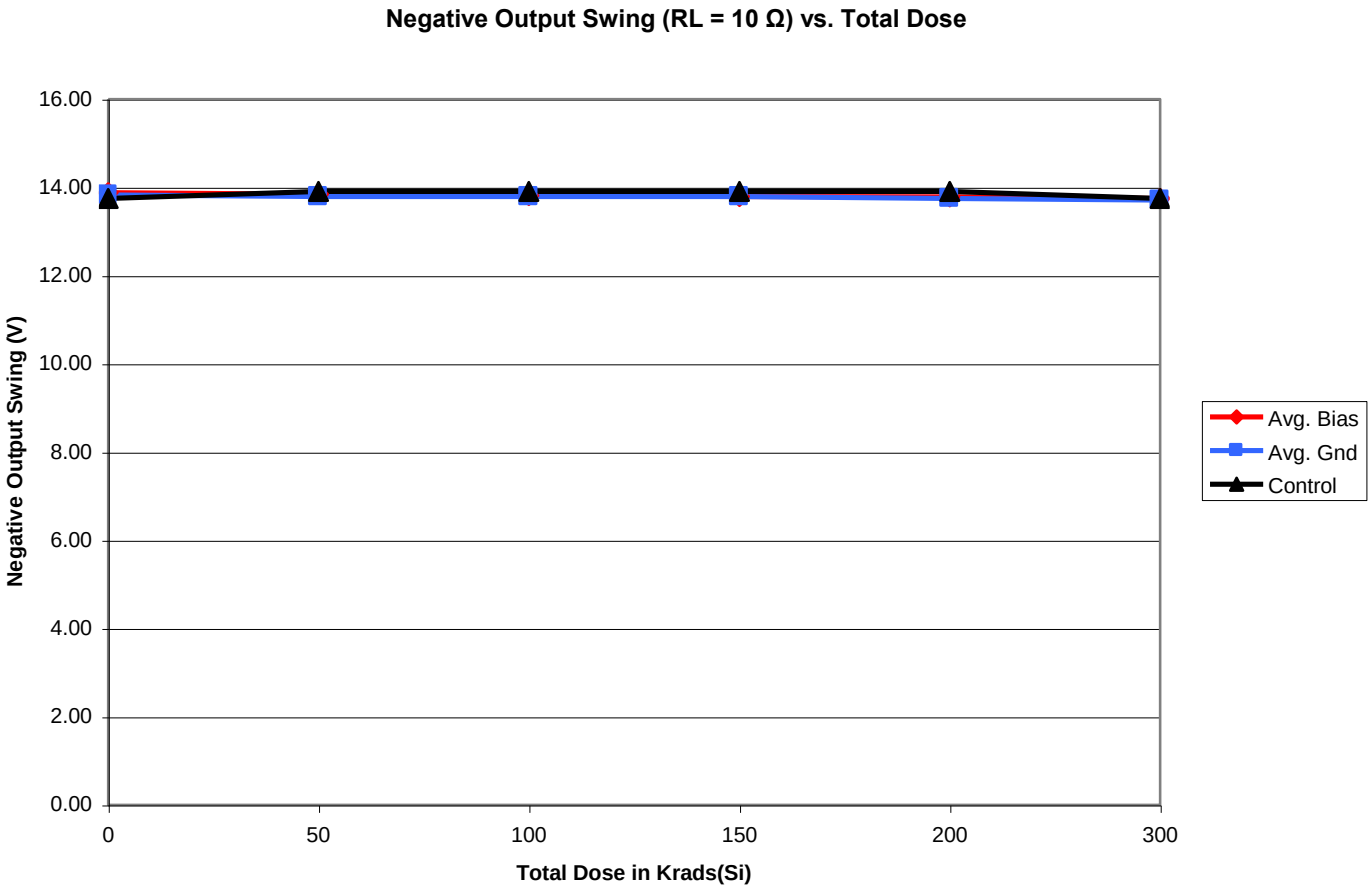


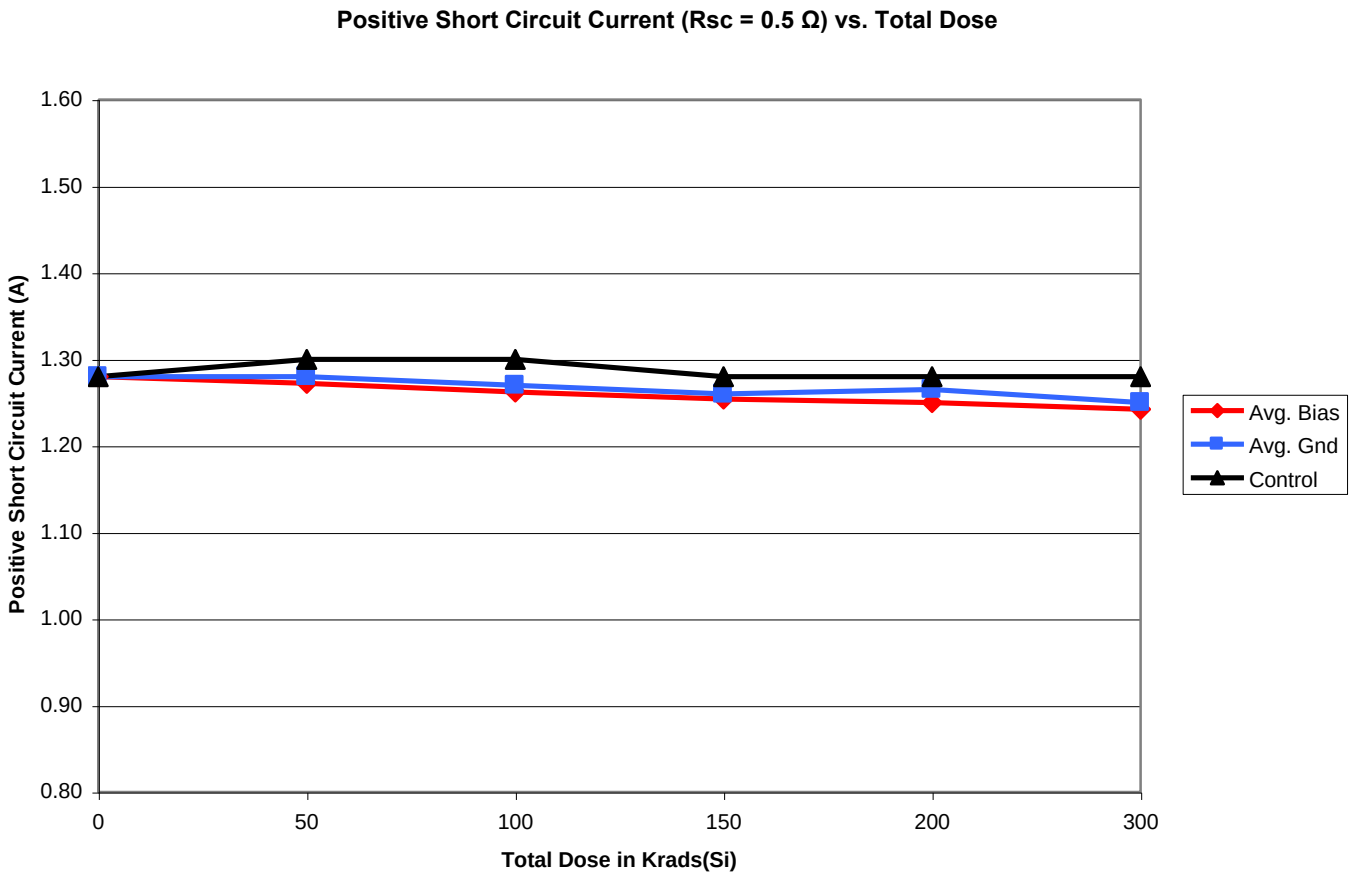

Power Supply Rejection Ratio vs. Total Dose
Power Supply Rejection Ratio (dB)
140.0
130.0
120.0
110.0
100.0
90.0
80.0
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Positive Output Swing (RL = 100 Ω) vs. Total Dose
Positive Output Swing (V)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

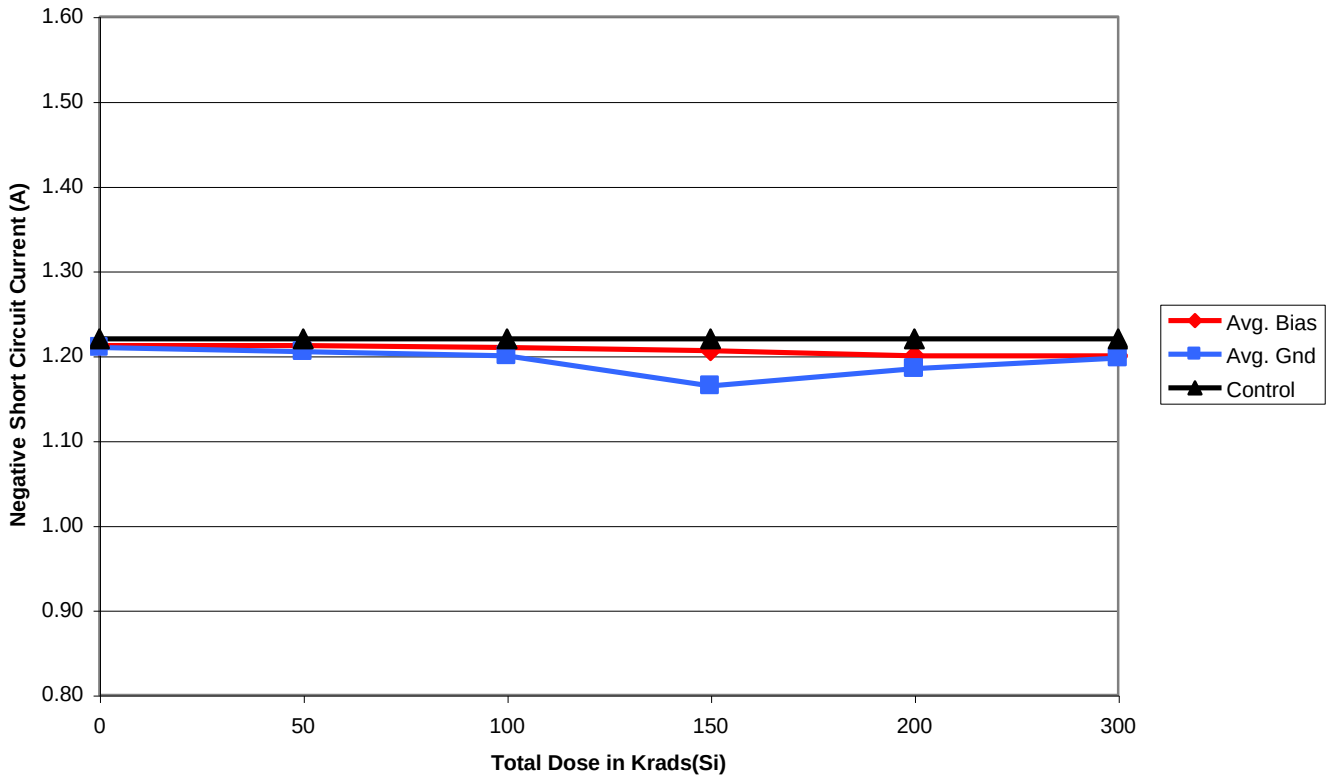

Negative Output Swing (RL = 100 Ω) vs. Total Dose
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Negative Output Swing (V)
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Positive Output Swing (RL =10 Ω) vs. Total Dose
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Poitive Output Swing (V)
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

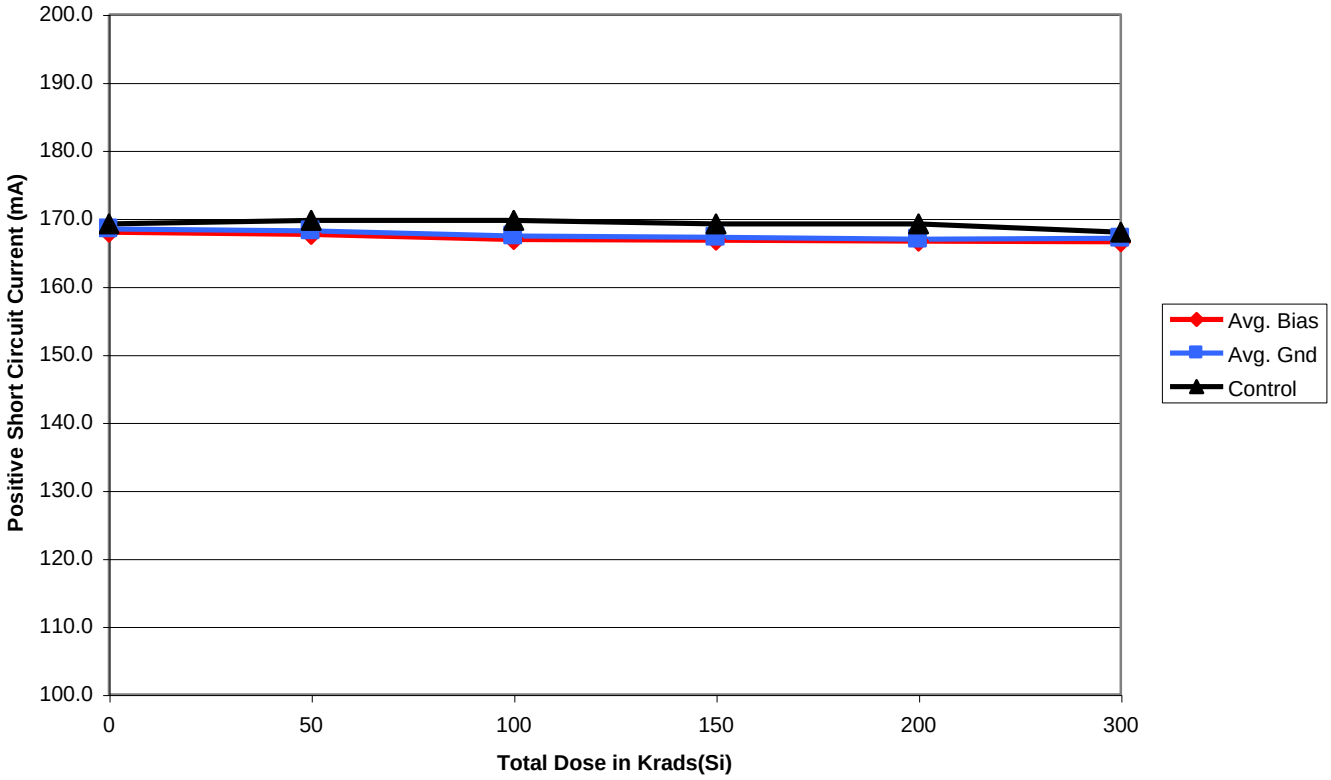

Negative Output Swing (RL = 10 Ω) vs. Total Dose
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Negative Output Swing (V)
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control


Positive Short Circuit Current (Rsc = 0.5 Ω) vs. Total Dose
1.60
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
Positive Short Circuit Current (A)
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

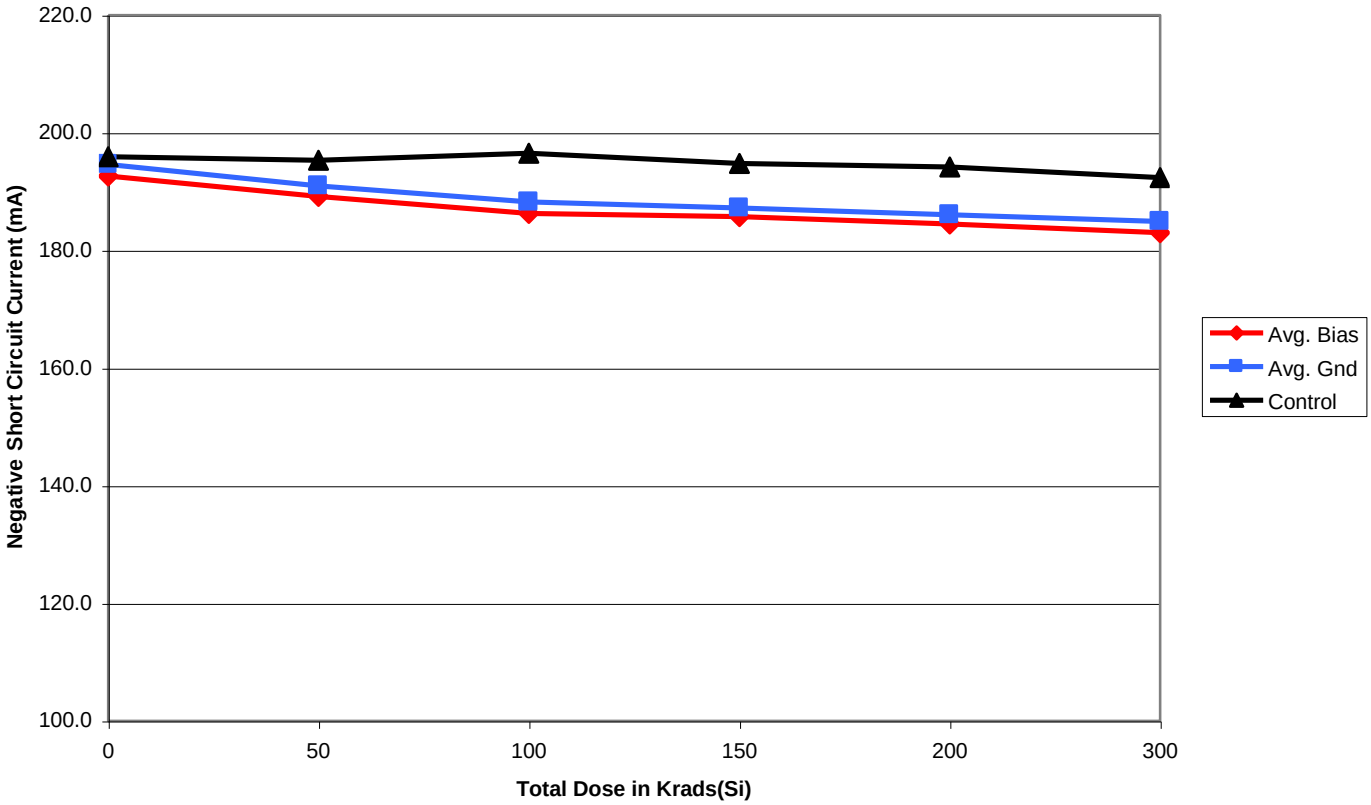
Negative Short Circuit Current (Rsc = 0.5 Ω) vs. Total Dose



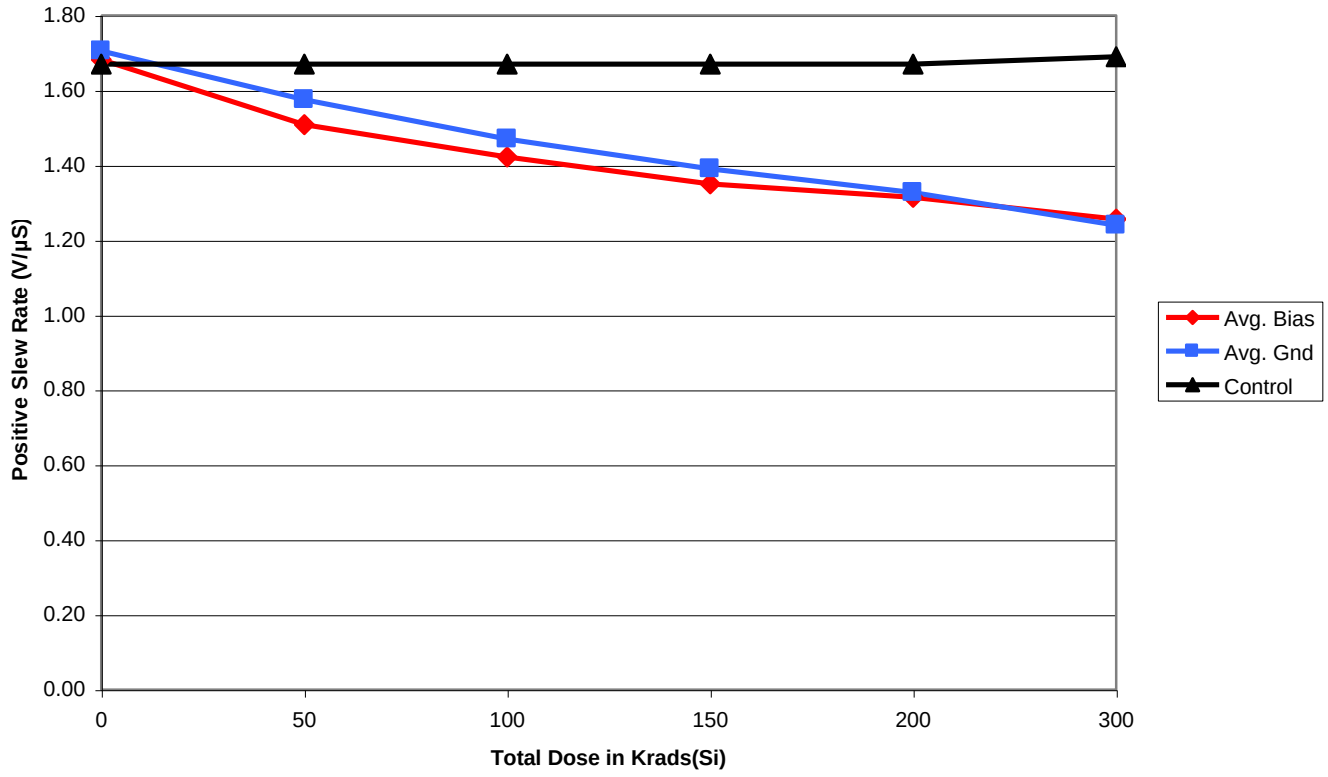
Positive Short Circuit Current (Rsc = 5 Ω) vs. Total Dose



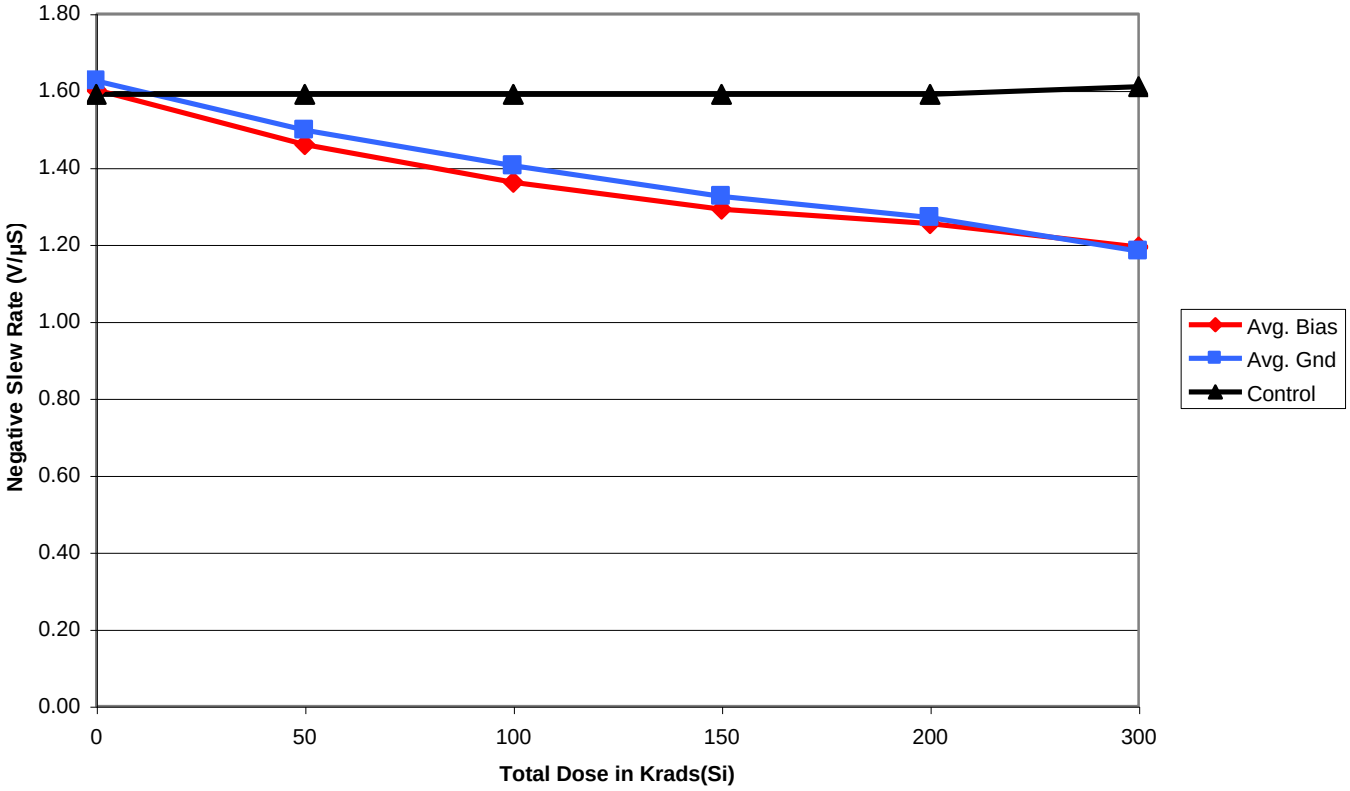
Negative Short Circuit Current (Rsc = 5 Ω) vs. Total Dose



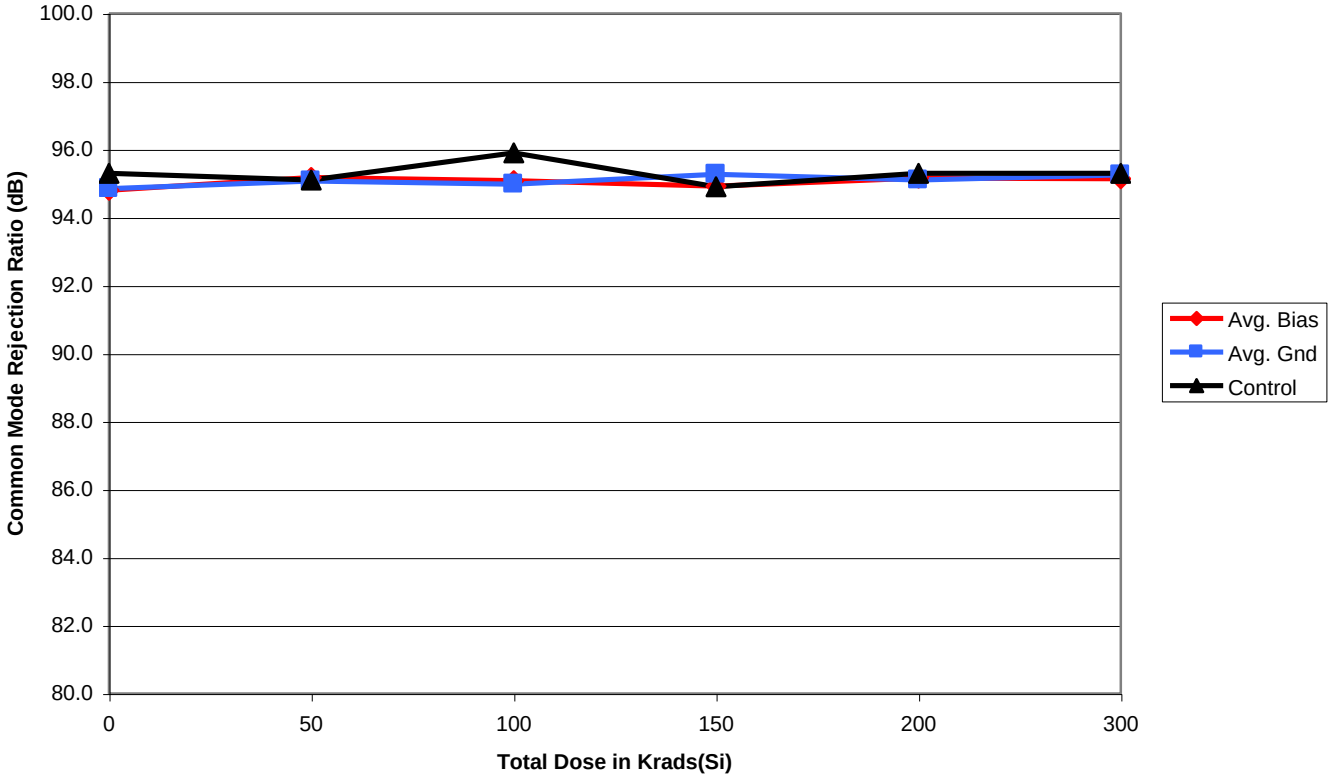
Positive Slew Rate vs. Total Dose

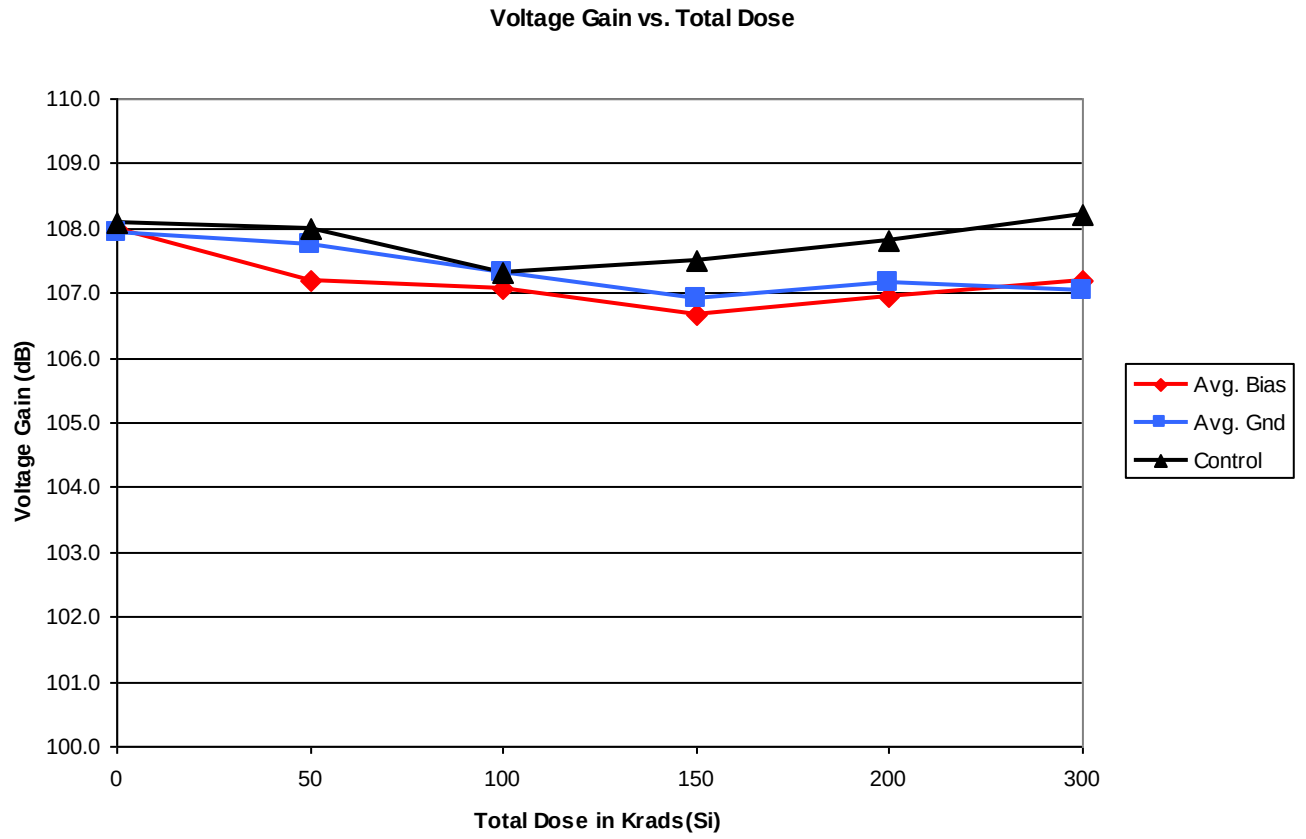


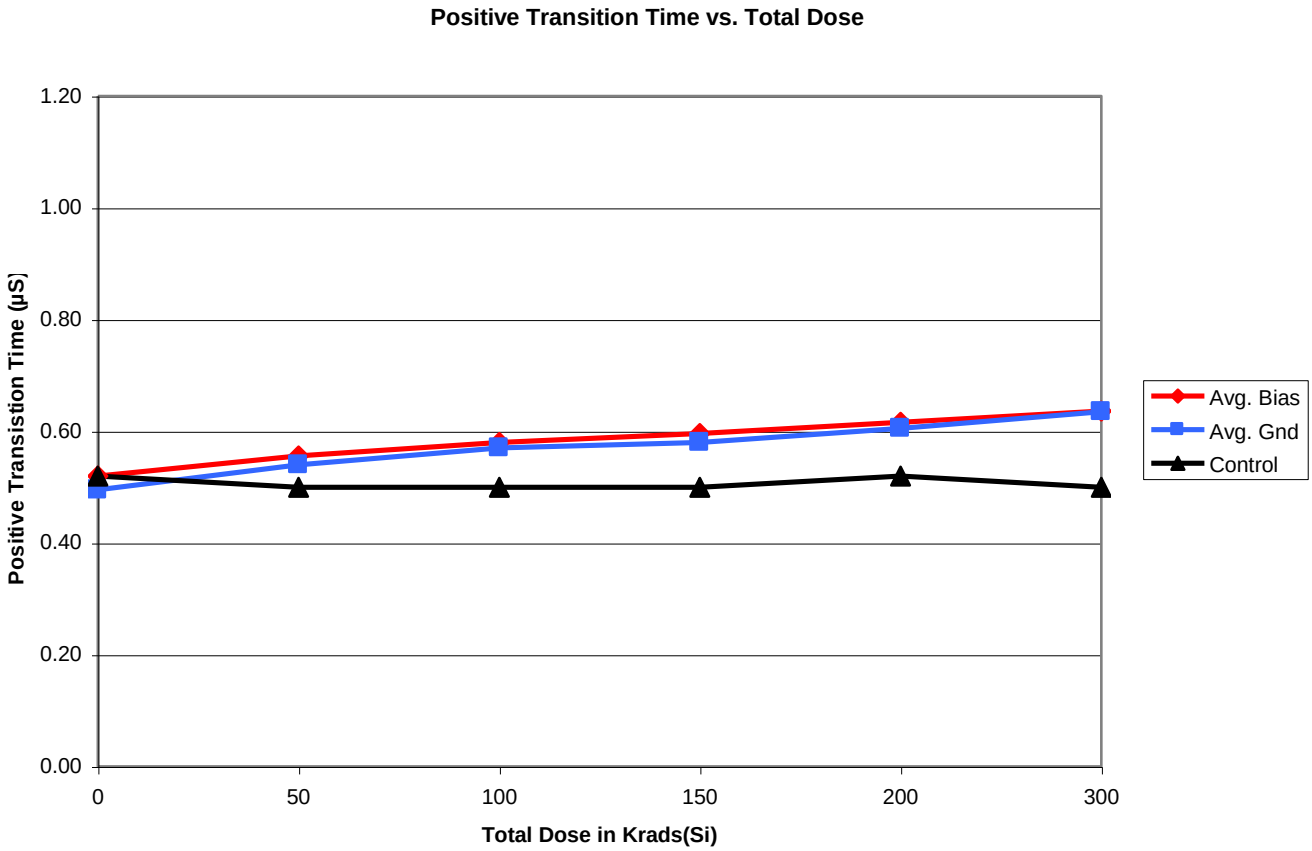
Negative Slew Rate vs. Total Dose



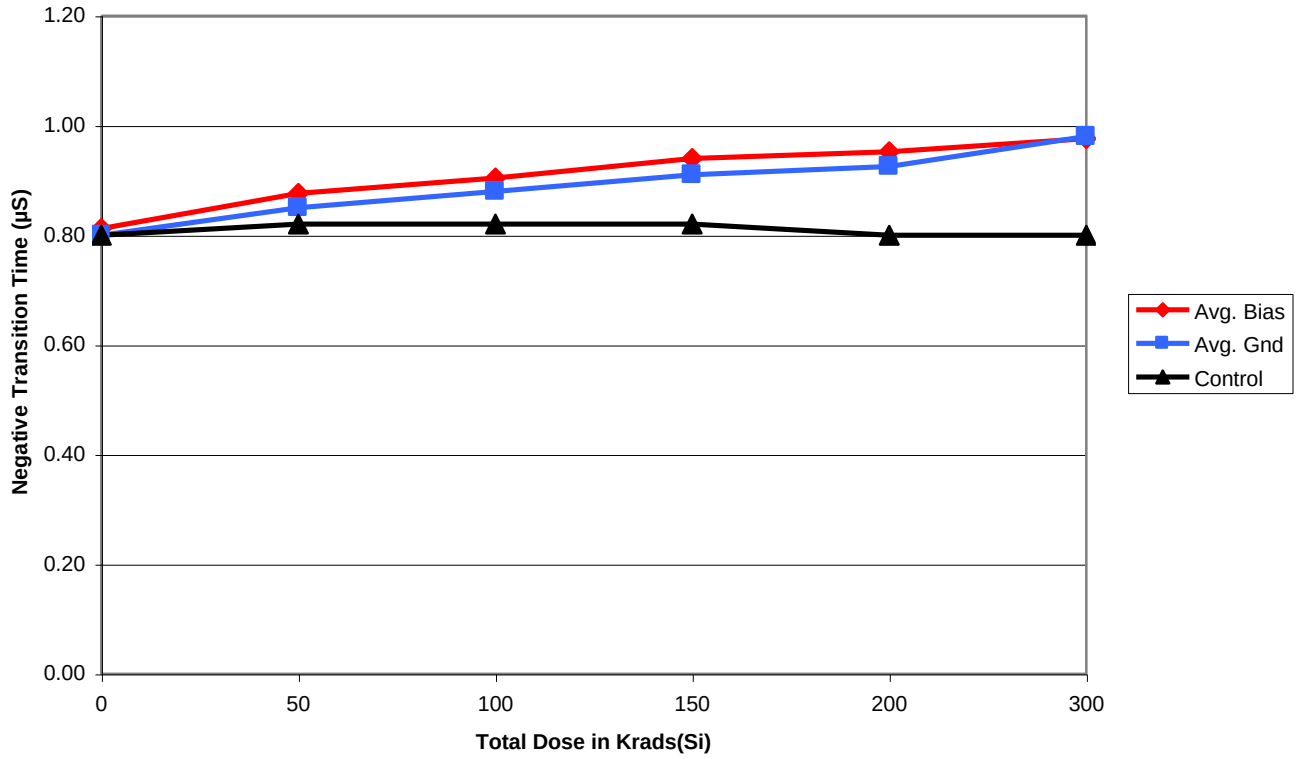
Common Mode Rejection Ratio vs. Total Dose



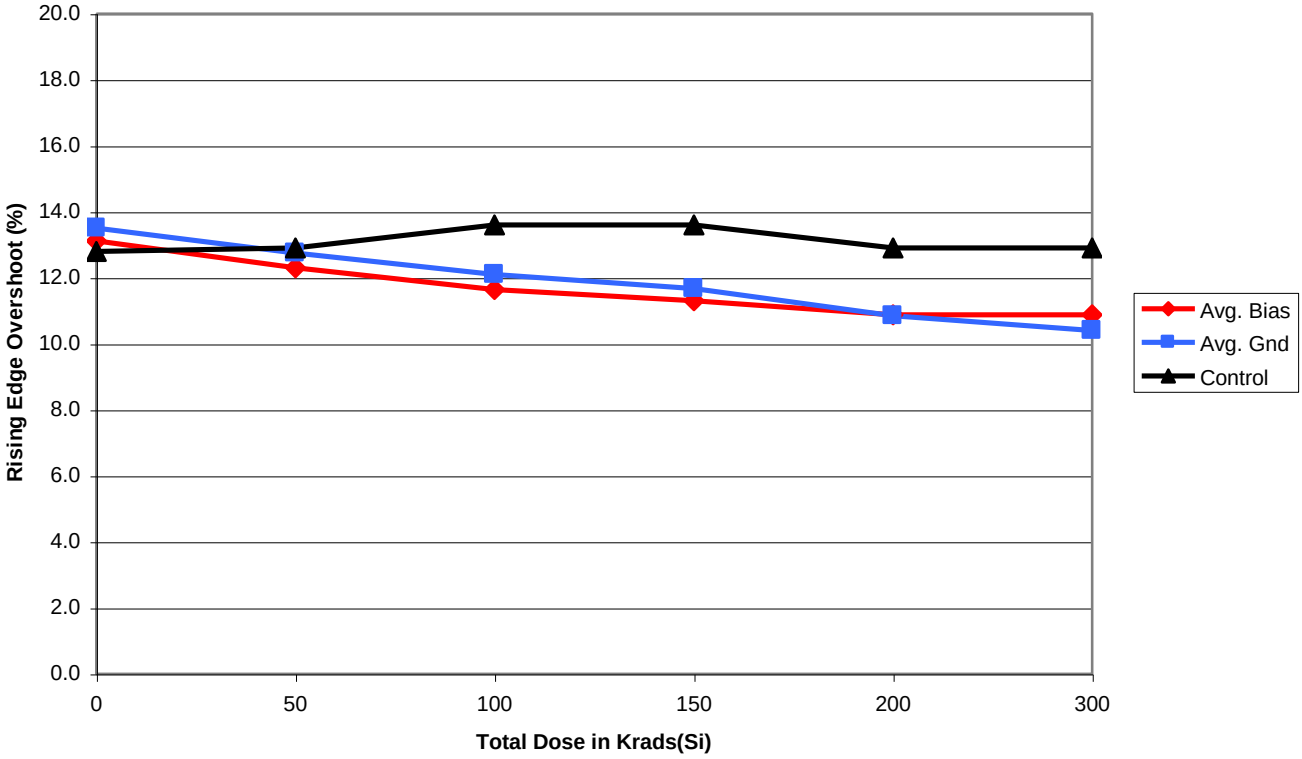

Voltage Gain vs. Total Dose
110.0
109.0
108.0
107.0
106.0
105.0
104.0
103.0
102.0
101.0
100.0
Voltage Gain (dB)
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

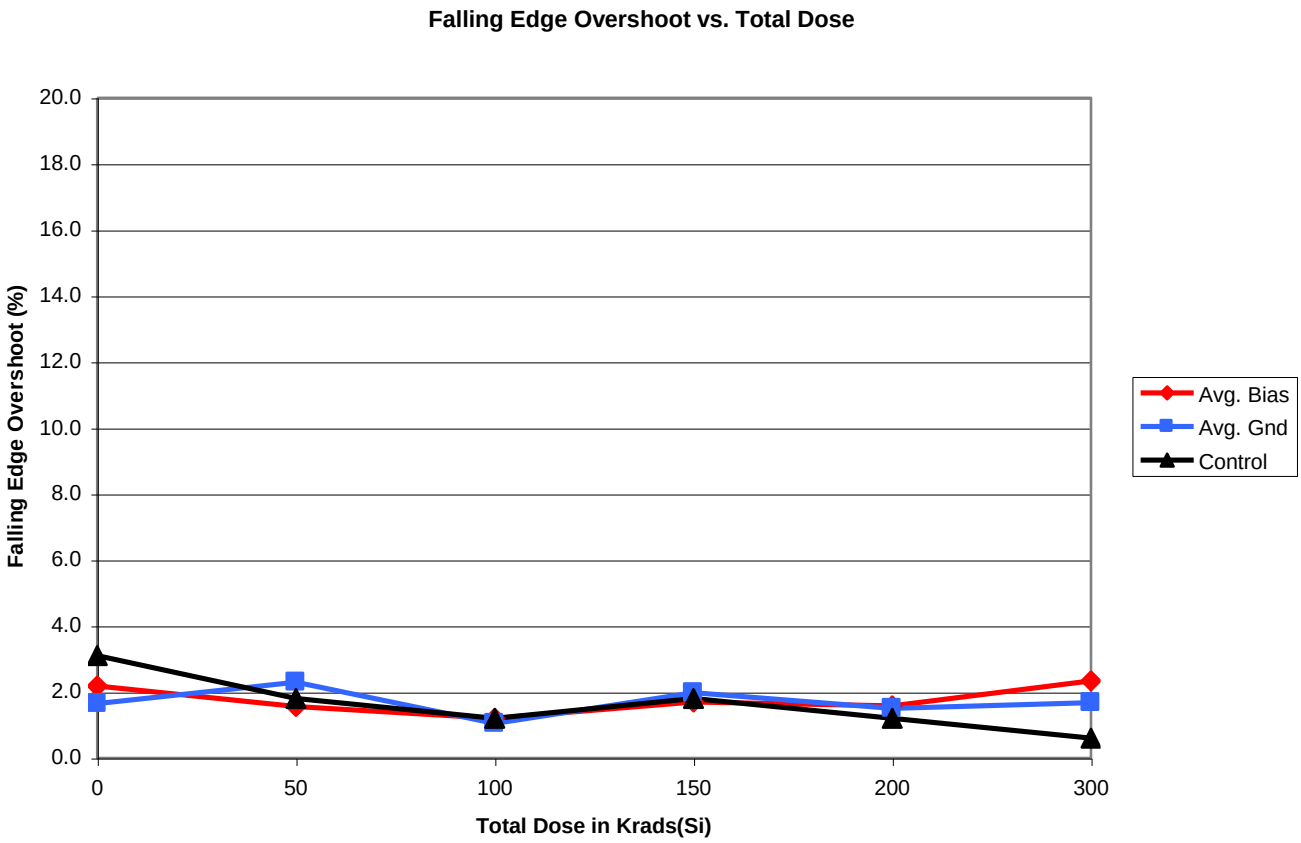

Positive Transition Time vs. Total Dose
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Positive Transistion Time (µS)
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

Negative Transition Time vs. Total Dose



Rising Edge Overshoot vs. Total Dose




Falling Edge Overshoot vs. Total Dose
Falling Edge Overshoot (%)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
50
100
150
200
300
Total Dose in Krads(Si)
Avg. Bias
Avg. Gnd
Control

Total Dose Radiation Test Report

MSK 106RH

Radiation Hardened High Power Op Amp

January 3, 2005
Updated on August 4, 2006

B. Erwin
J. Swistak

M.S. Kennedy Corporation
Liverpool, NY

I. Introduction:

The total dose radiation test plan for the MSK 106RH was developed to qualify the device as a radiation hardened device up to 100 KRADS(Si). The testing was performed beyond 100 KRAD to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the hybrid, but simply offers designers insight to the critical parameter-shifts up to the specified total dose level.

MIL-STD-883 Method 1019 and ASTM F1892-98 were used as guidelines in the development and implementation of the total dose test plan for the MSK 106RH.

II. Radiation Source:

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. Thermo luminescence dosimetry was performed and the dose rate was determined to be 151 Rads(Si)/sec. The total dose schedule can be found in Table I.

III. Test Setup:

All test samples were subjected to Group A Electrical Test in accordance with the device data sheet. In addition, all devices received 320 hours of burn-in per MIL-STD-883 Method 1015 and were fully screened IAW MIL-PRF-38534 Class K. For test platform verification, one control device was tested at 25°C. Eight devices were then tested at 25°C, prior to irradiation, and were found to be within acceptable test limits.

The devices were vertically aligned with the radiation source and enclosed in a lead/aluminum container during irradiation. Four devices were kept under bias during irradiation. The bias circuit schematic can be found in the MSK 106RH Total Dose Radiation Test Plan. Four devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted using foil lined carriers and were transported to the MSK automatic electrical test platform and tested IAW MSK device data sheet. Testing was performed on irradiated devices, as well as the control device, at each total dose level. Electrical tests were completed within one hour of irradiation. At the conclusion of irradiation and testing all devices were subjected to a 160 hour anneal at 100°C. Electrical tests were then performed to determine the effects of annealing for informational purposes only.

IV. Data:

All performance curves are averaged from the test results of the biased and unbiased devices respectively.

V. Summary:

Based on the test data recorded during radiation testing, the MSK 106RH easily qualified as a 100 KRADS(Si) radiation hardened device. Further analysis of the data shows the device to offer tolerance to total dose radiation to levels of 300 KRADS(Si).

Nearly all test data fell within pre irradiation test limits up to a cumulative dose level of 300 KRADS(Si). Quiescent current and slew rate showed a slight decrease over the entire cumulative dose range.

Annealing the devices at 100°C for 160 hours resulted in a shift back towards pre-irradiation results for all test parameters.

An ELDRS test is planned for the future to determine the effects of low dose rate exposure.

Dosimetry Equipment:
Bruker Biospin #0141

Dose Rate = 151 Rads(Si)/Sec

Testing Performed:
11/17/2004

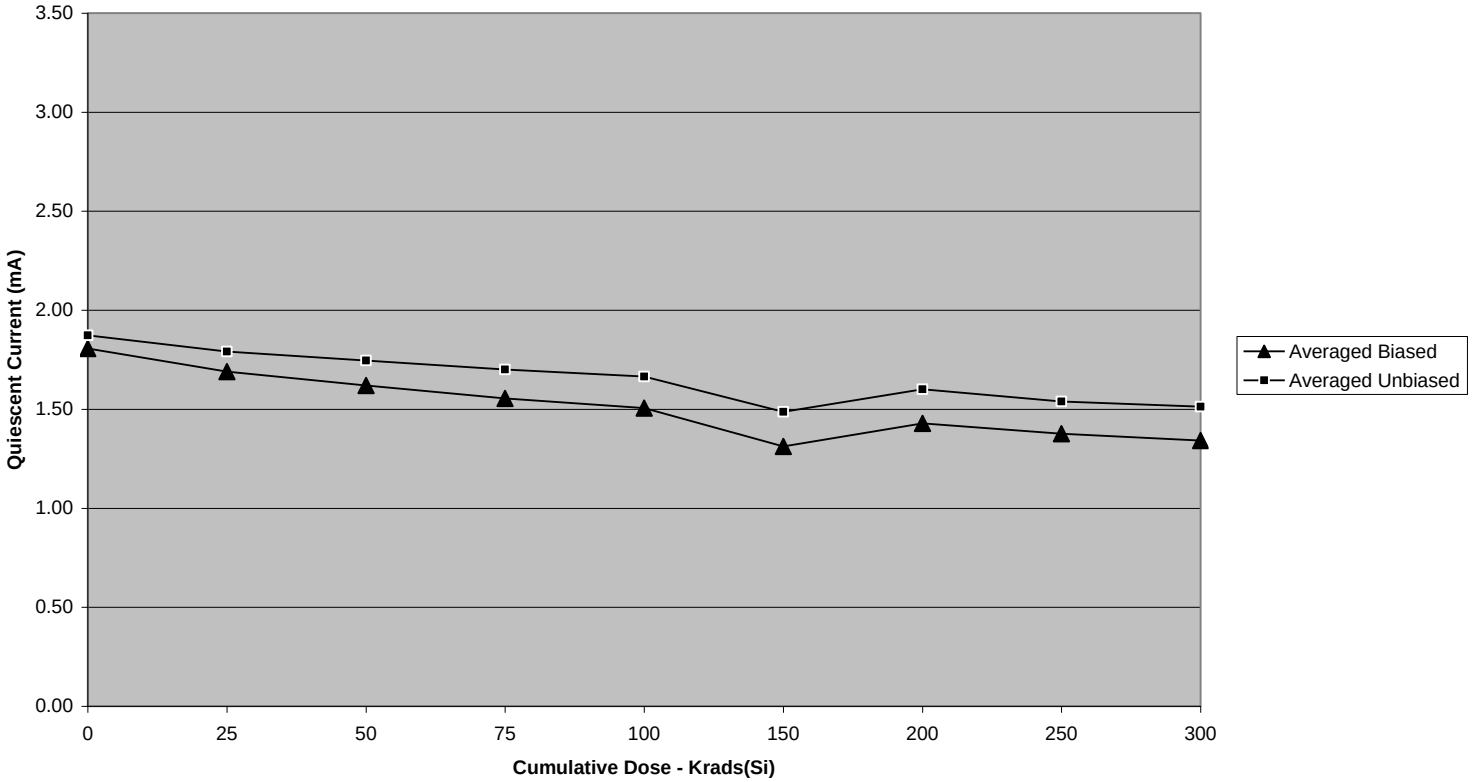
Biased MSK 5900RH		
Dose Time (min:sec)	Incremental Dose Rads(Si)	Cumulative Dose Rads(Si)
2:50	25,670	25,670
2:50	25,670	51,340
2:50	25,670	77,010
2:50	25,670	102,680
5:40	51,340	154,020
5:40	51,340	205,360
5:40	51,340	256,700
5:40	51,340	308,040

Unbiased MSK 5900RH		
Dose Time (min:sec)	Incremental Dose Rads(Si)	Cumulative Dose Rads(Si)
2:50	25,670	25,670
2:50	25,670	51,340
2:50	25,670	77,010
2:50	25,670	102,680
5:40	51,340	154,020
5:40	51,340	205,360
5:40	51,340	256,700
5:40	51,340	308,040

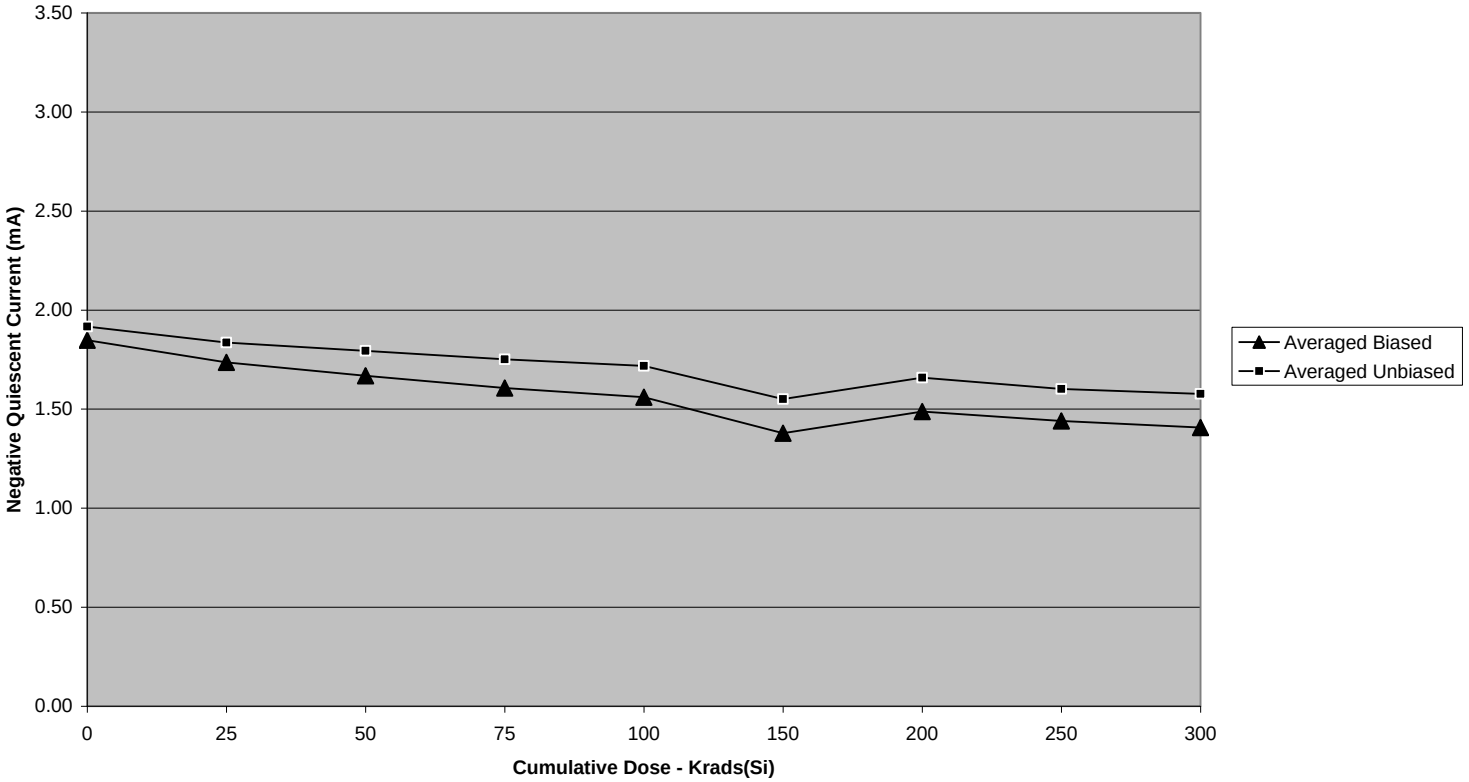
Table I

Dose Time, Incremental Dose and Total Cumulative Dose

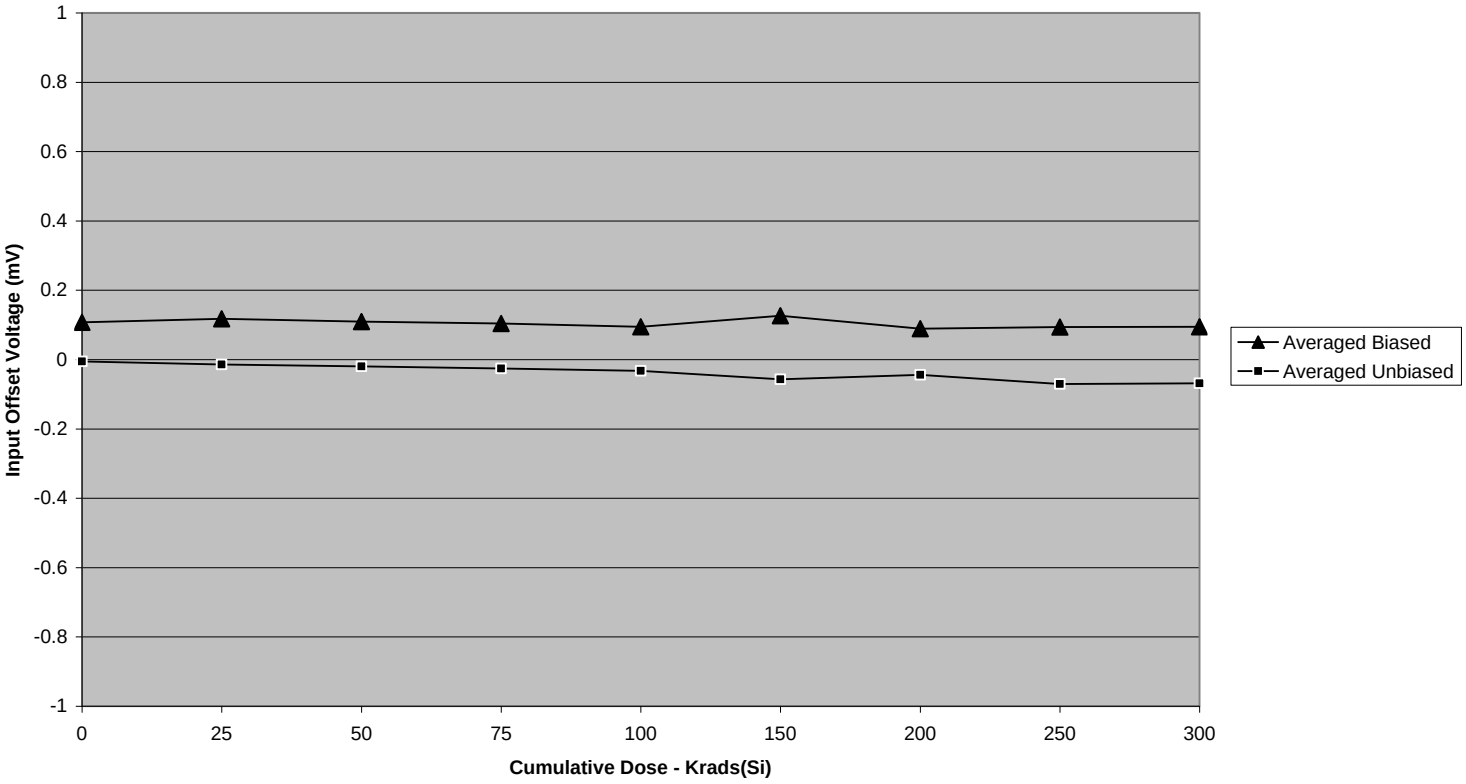
MSK 106RH Positive Quiescent Current



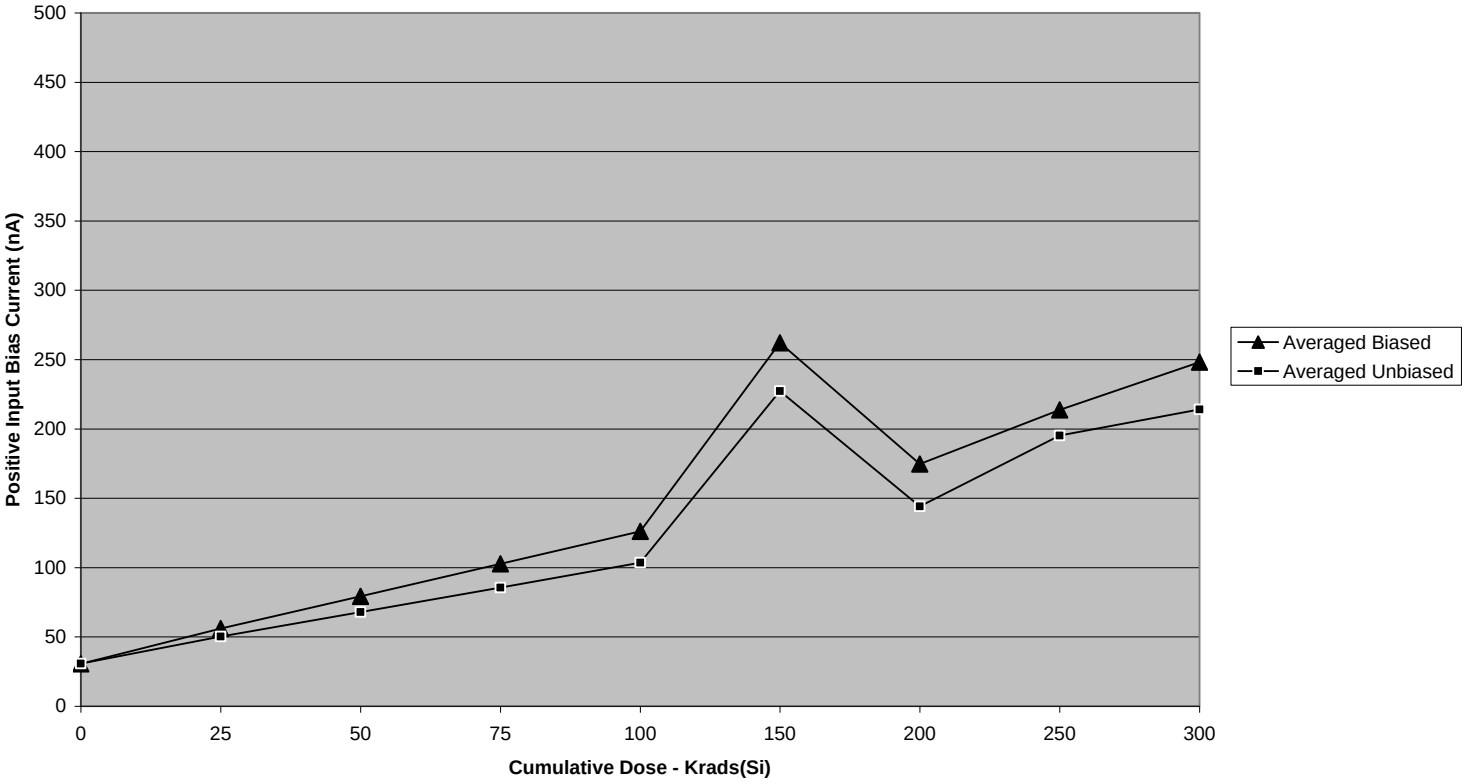
MSK 106RH Negative Quiescent Current



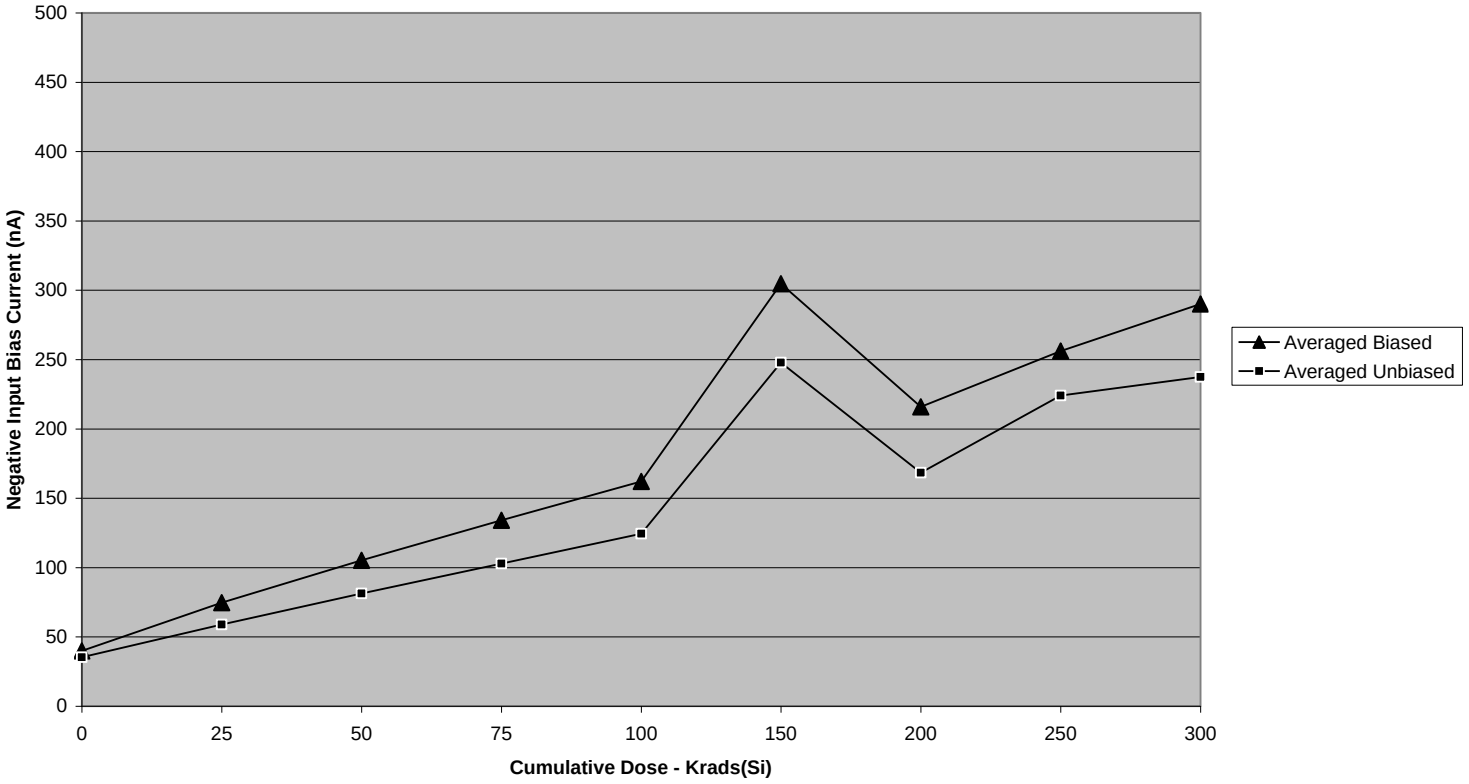
MSK 106RH Input Offset Voltage



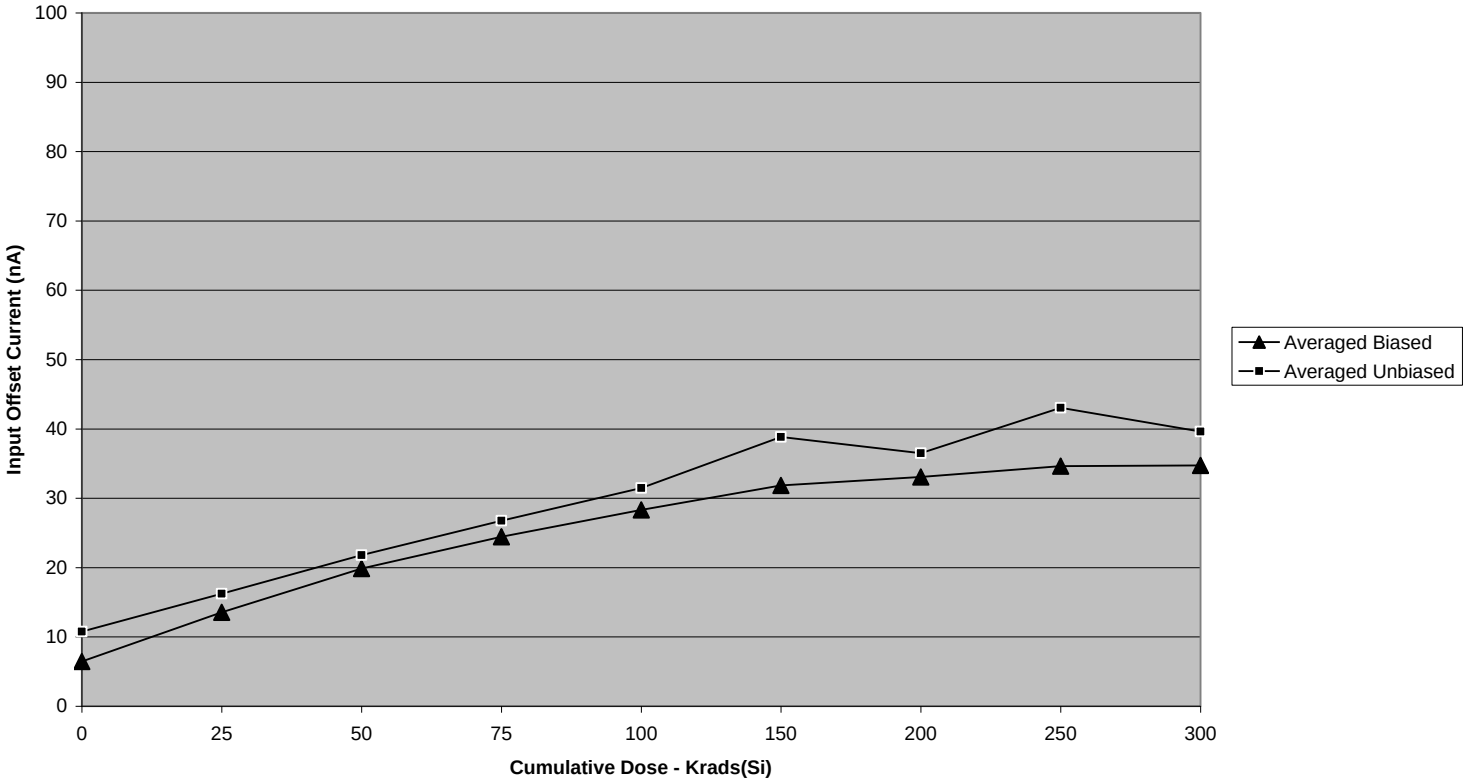
MSK 106RH Positive Input Bias Current



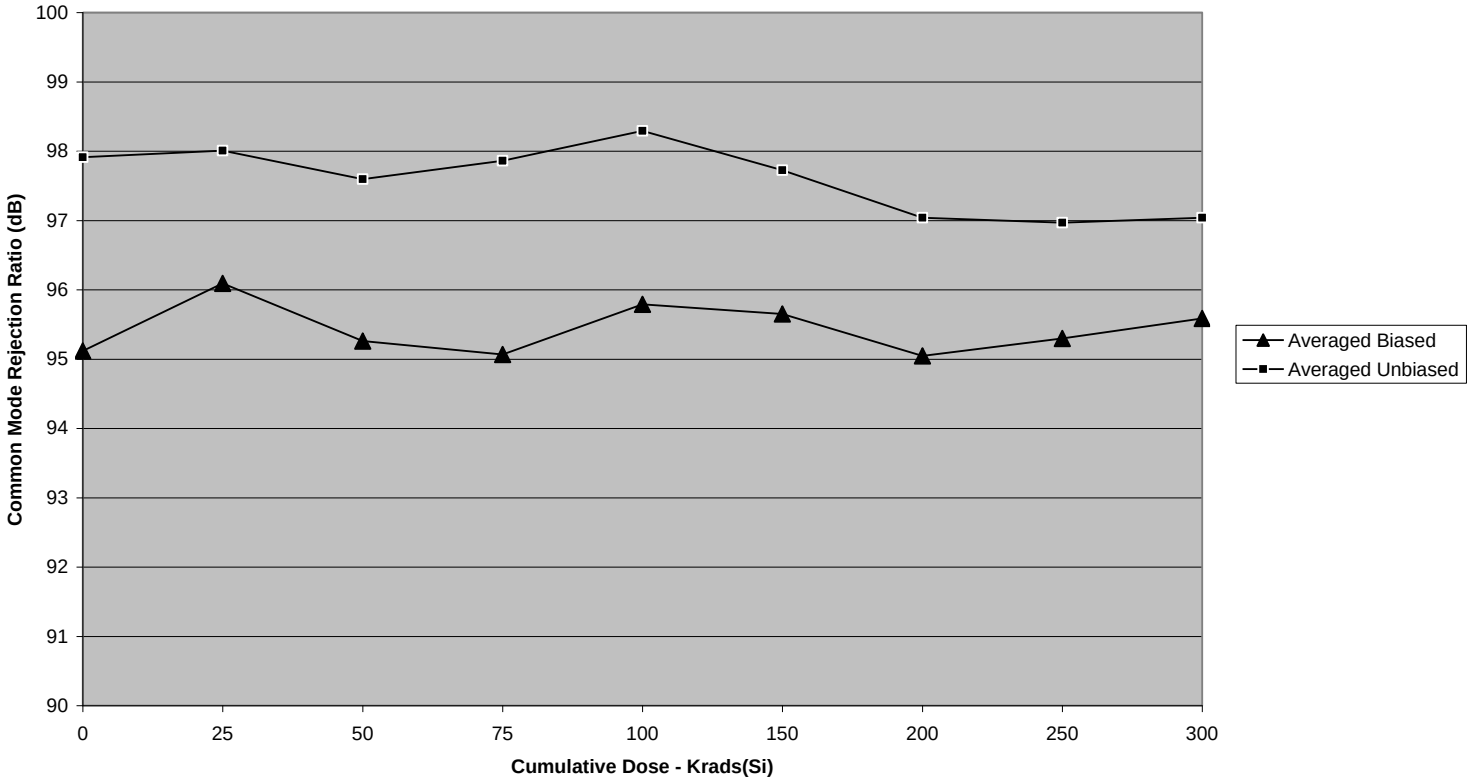
MSK 106RH Negative Input Bias Current



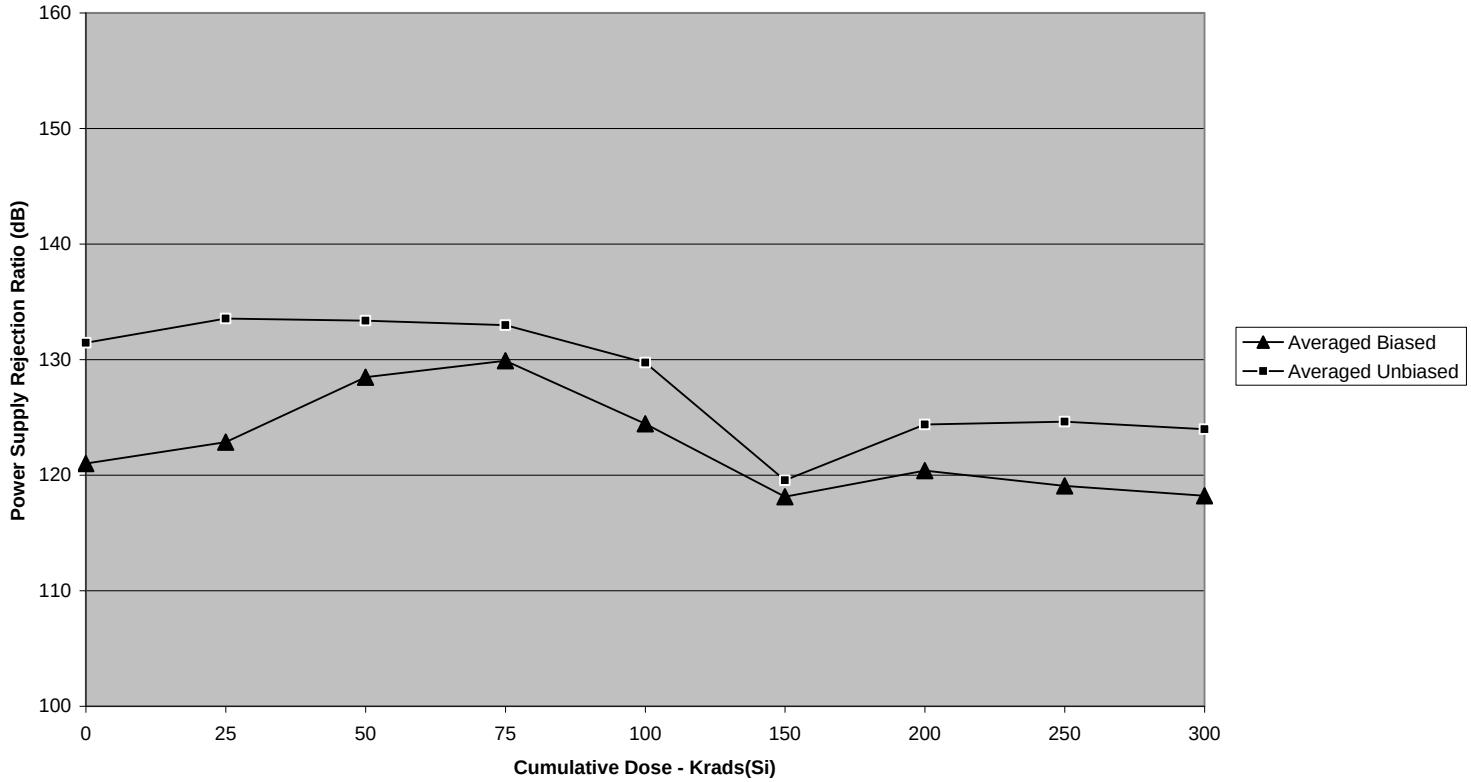
MSK 106RH Input Offset Current



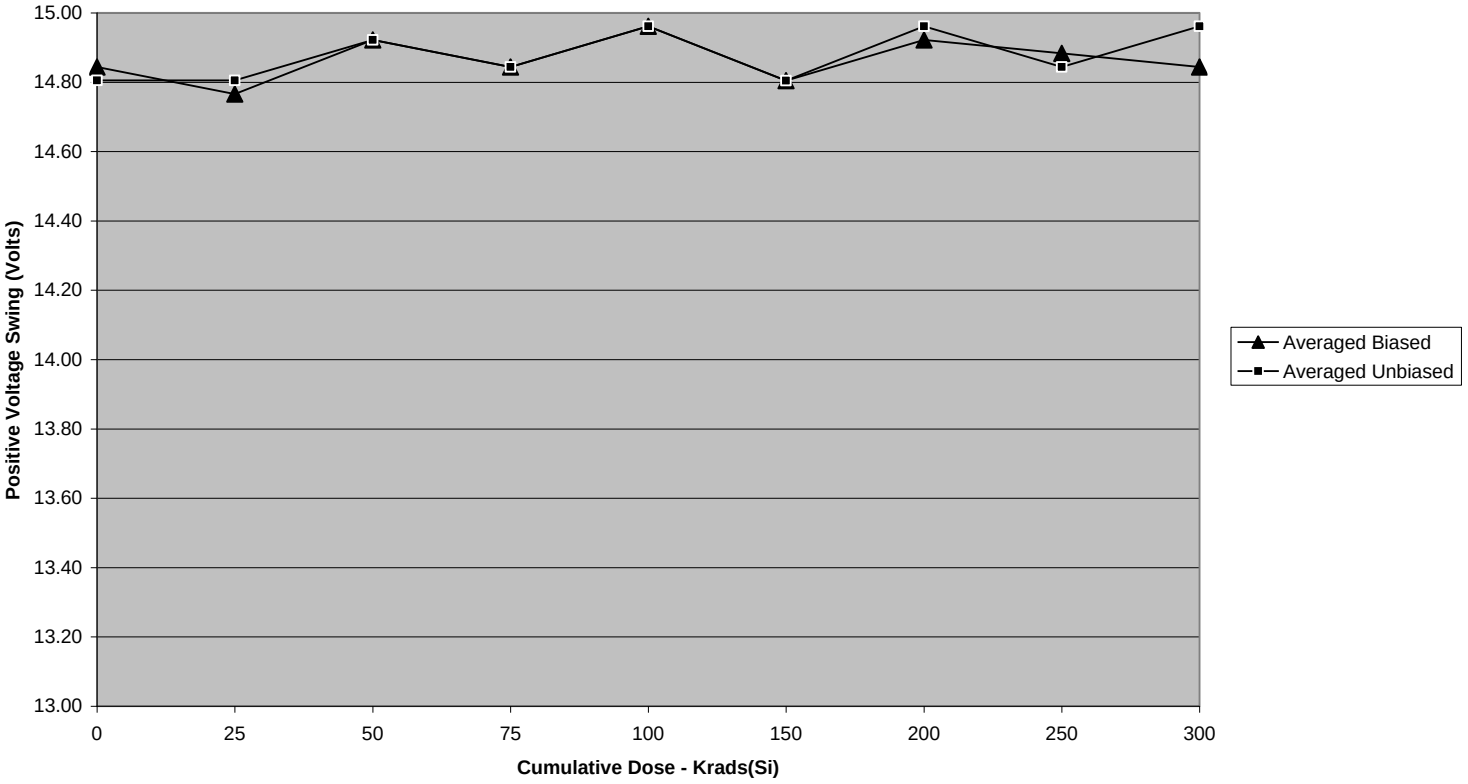
MSK 106RH Common Mode Rejection Ratio



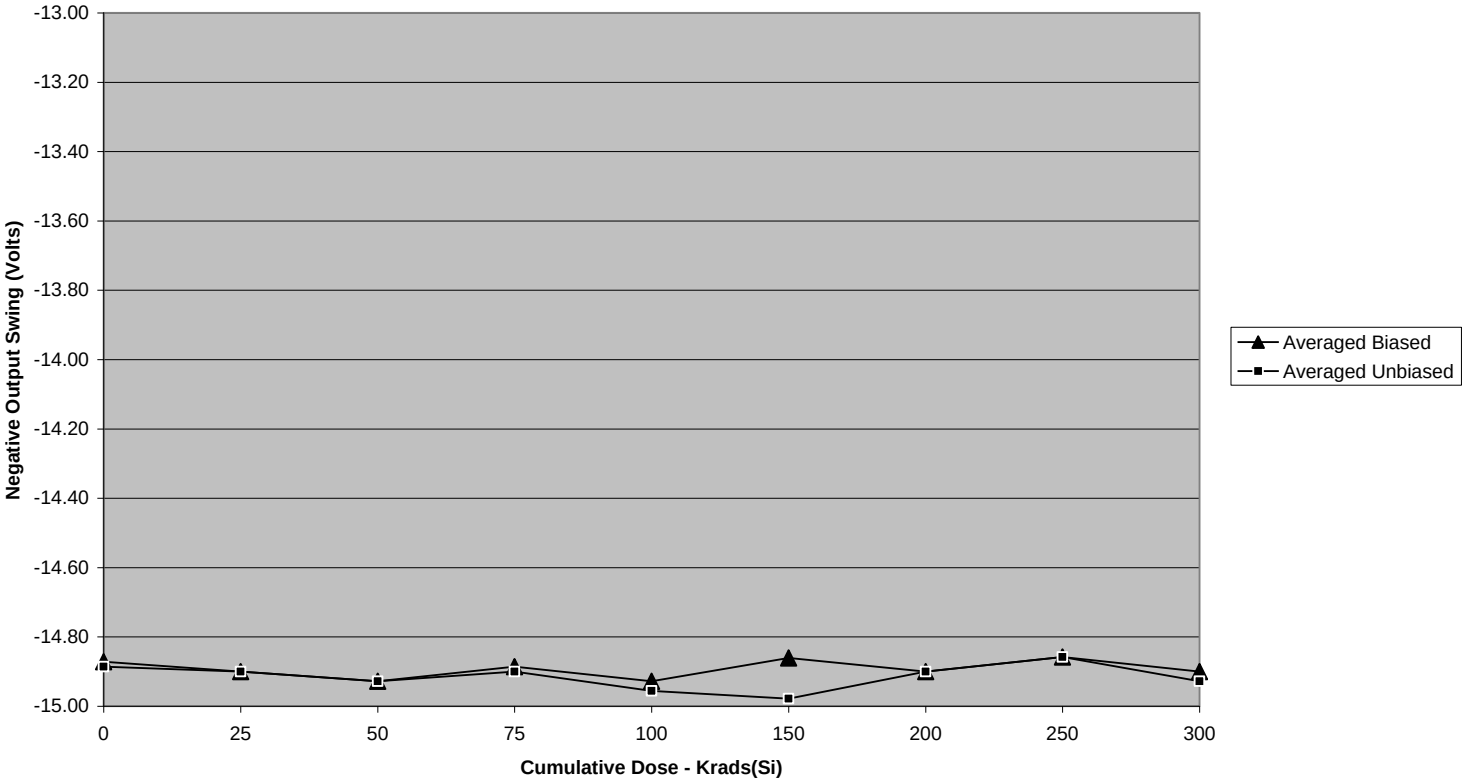
MSK 106RH Power Supply Rejection Ratio



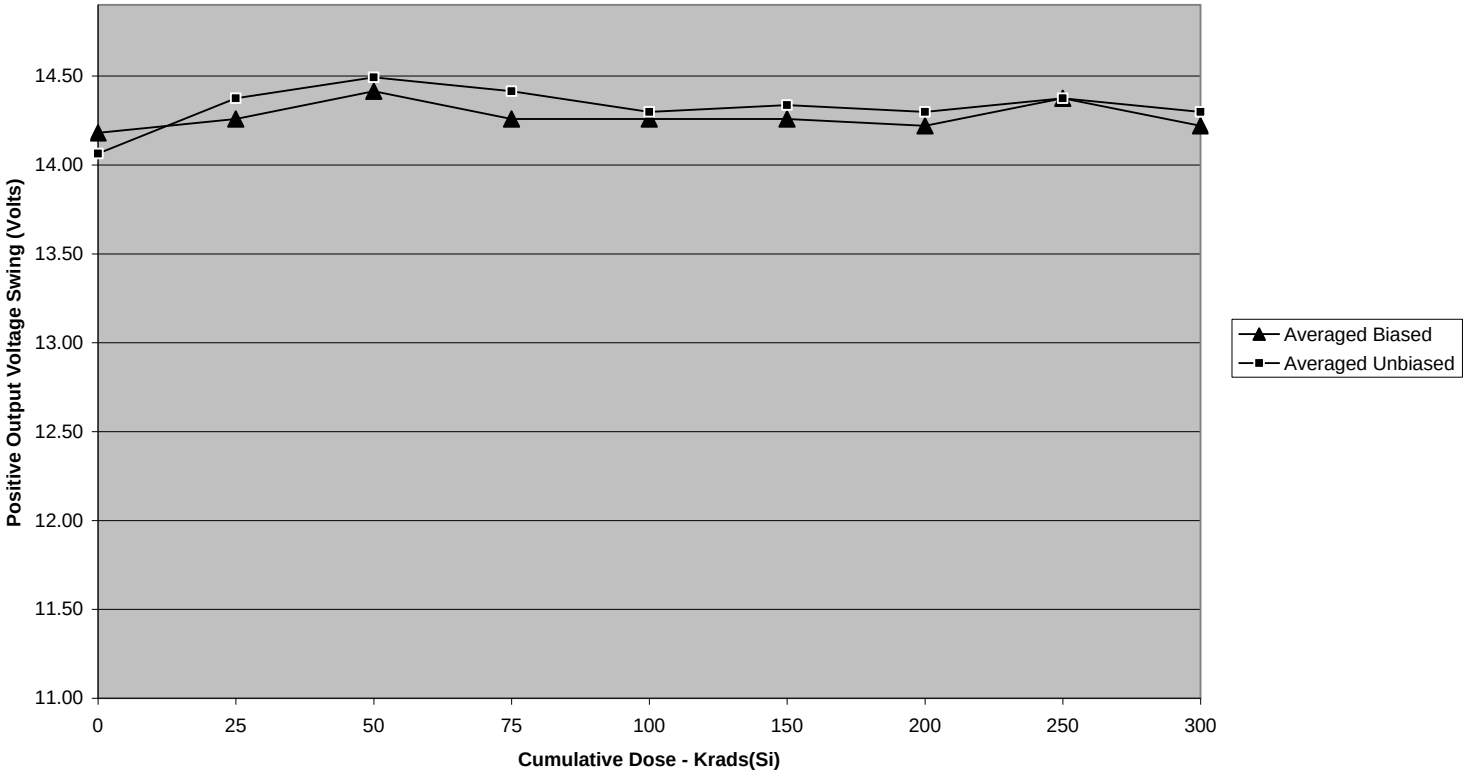
MSK 106RH Positive Voltage Swing - R_L = 100 Ohms



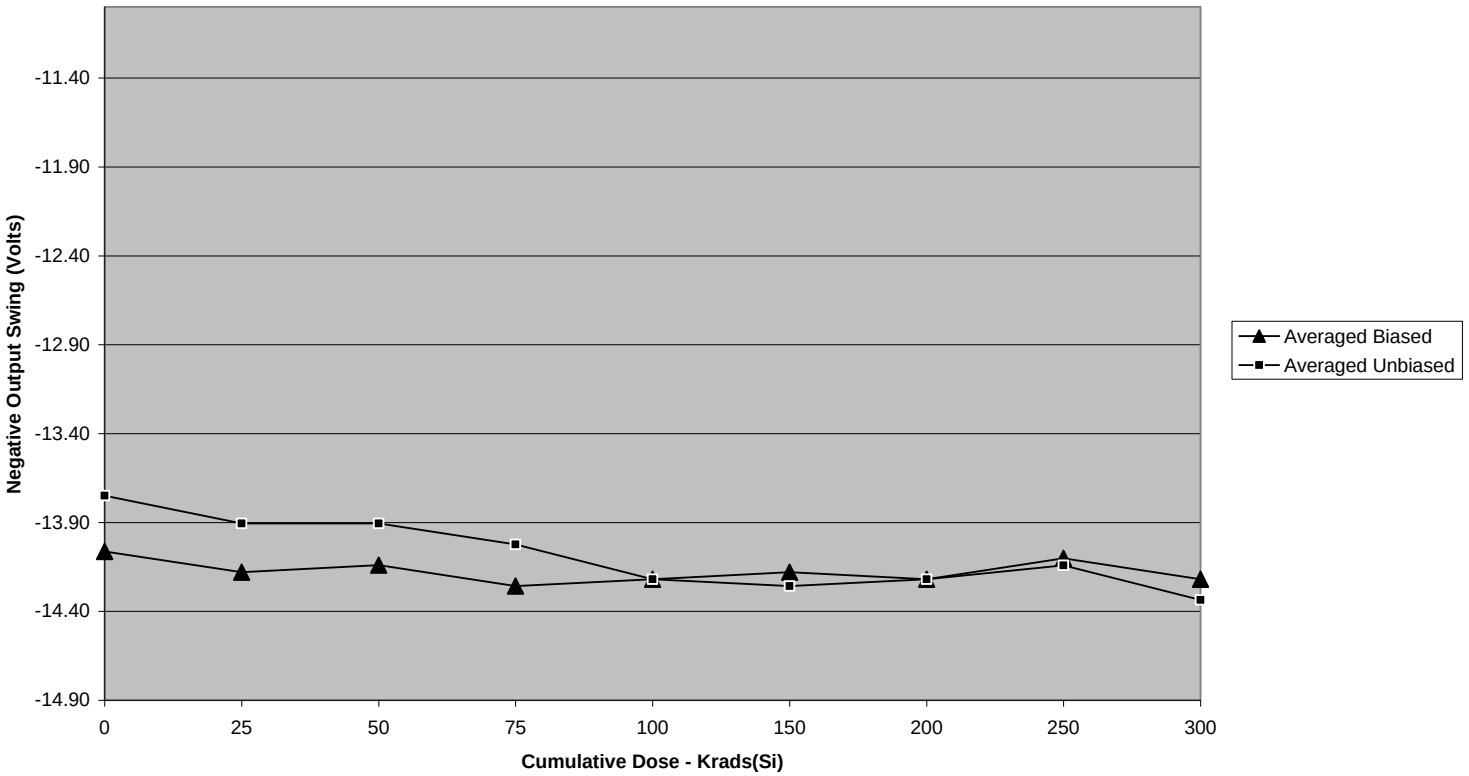
MSK 106RH Negative Output Swing - R_L = 100 Ohms



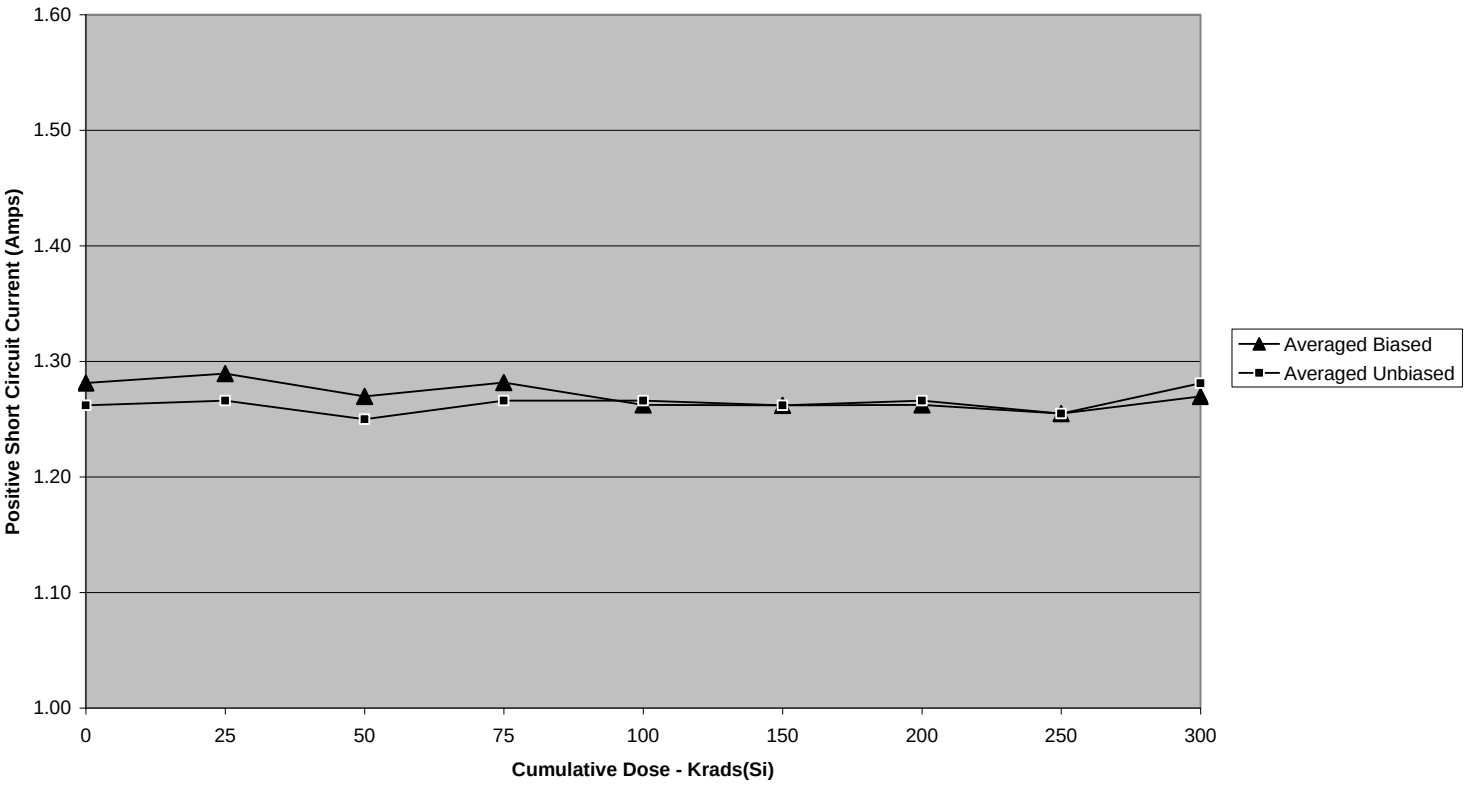
MSK 106RH Positive Output Swing - R_L = 10 Ohms



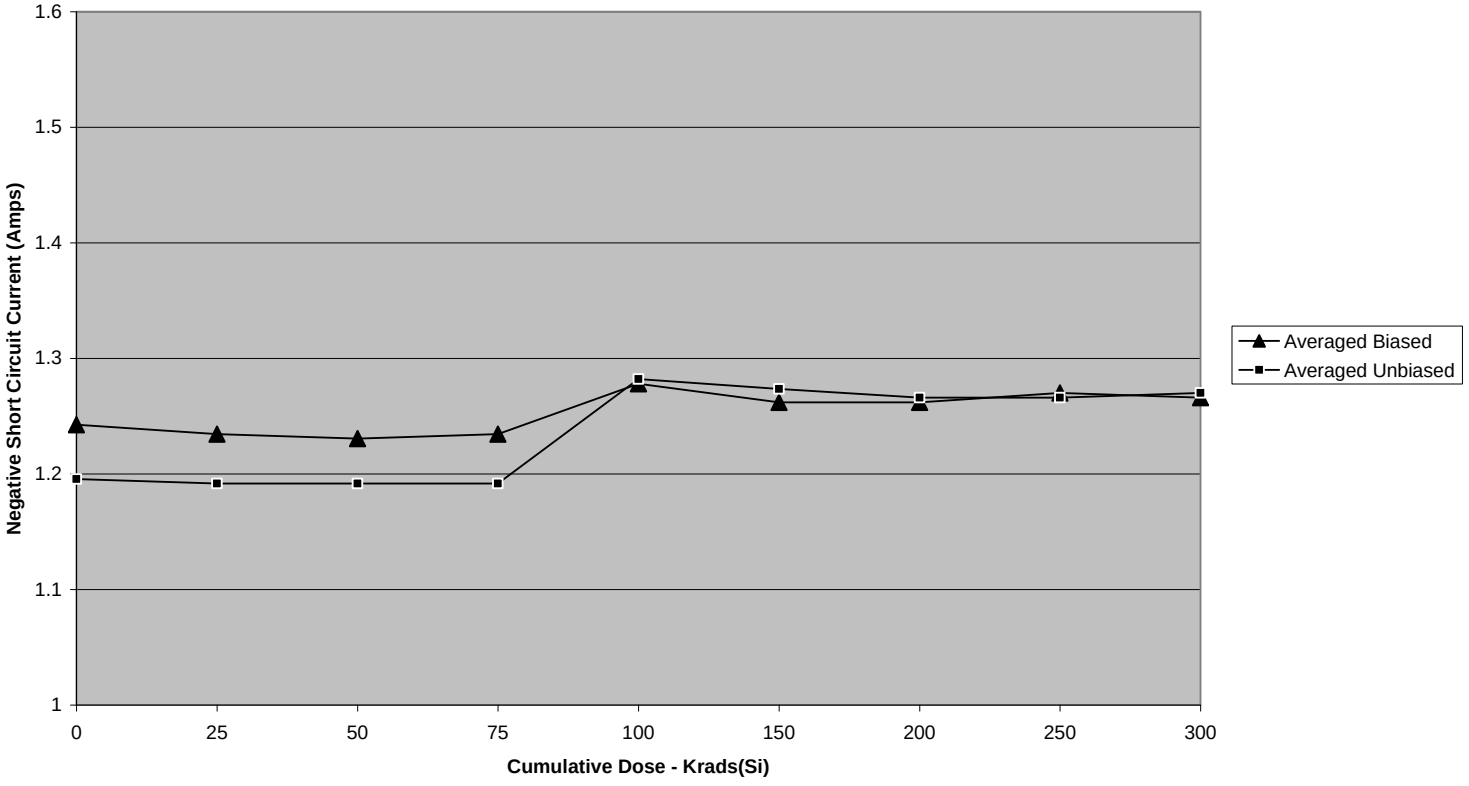
MSK 106RH Negative Output Swing - R_L = 10 Ohms



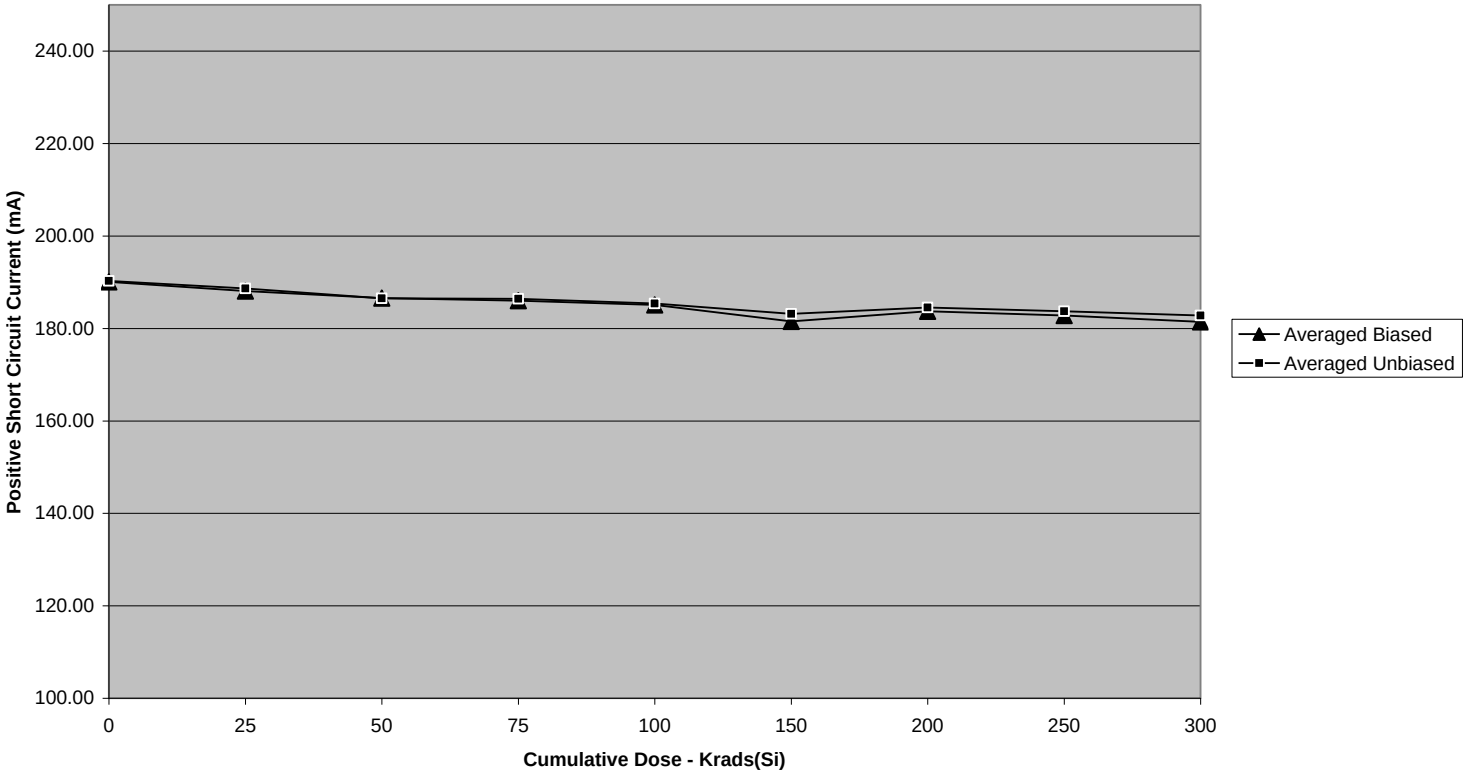
MSK 106RH Positive Short Circuit Current R_{SC} = 0.5 Ohms



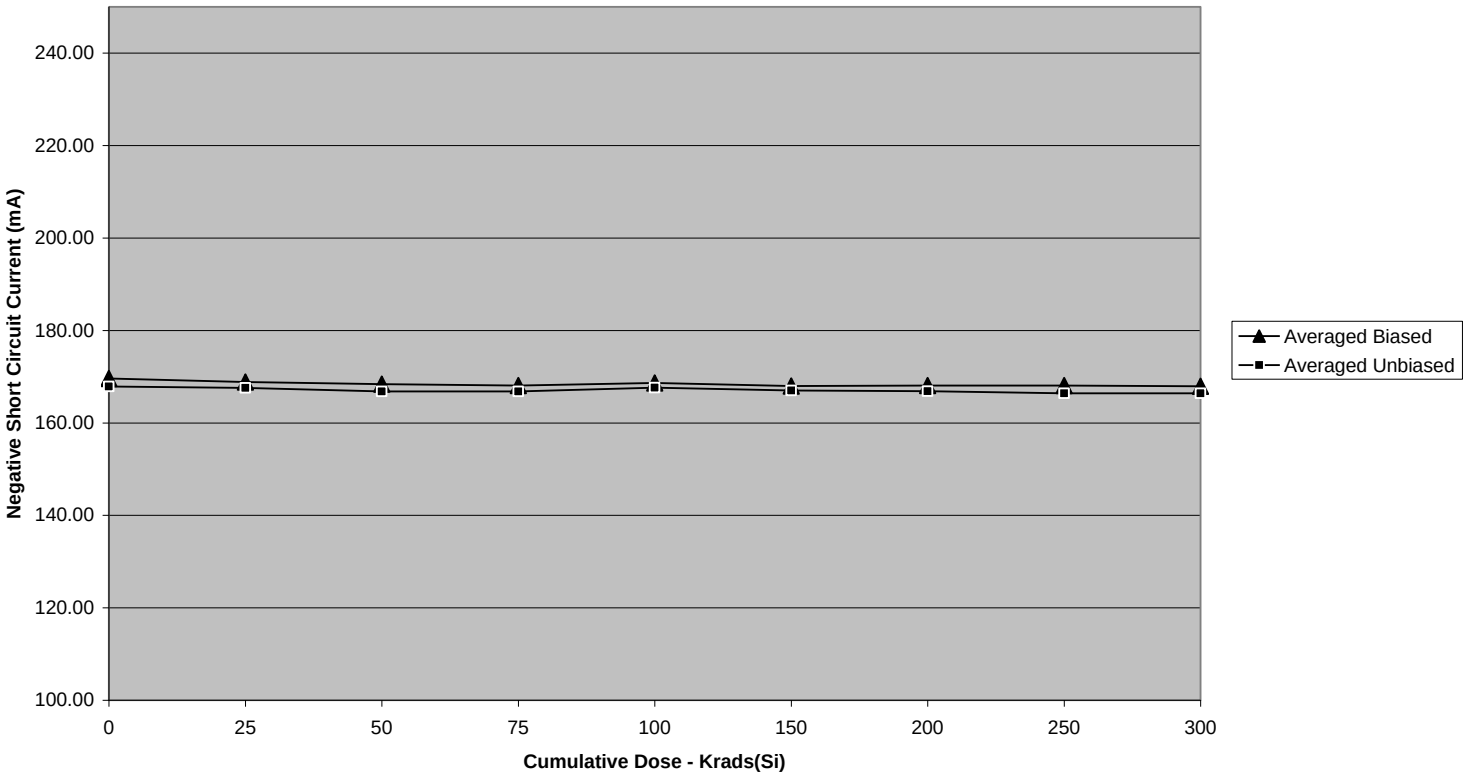
MSK 106RH Negative Short Circuit Current R_{SC} = 0.5 Ohms



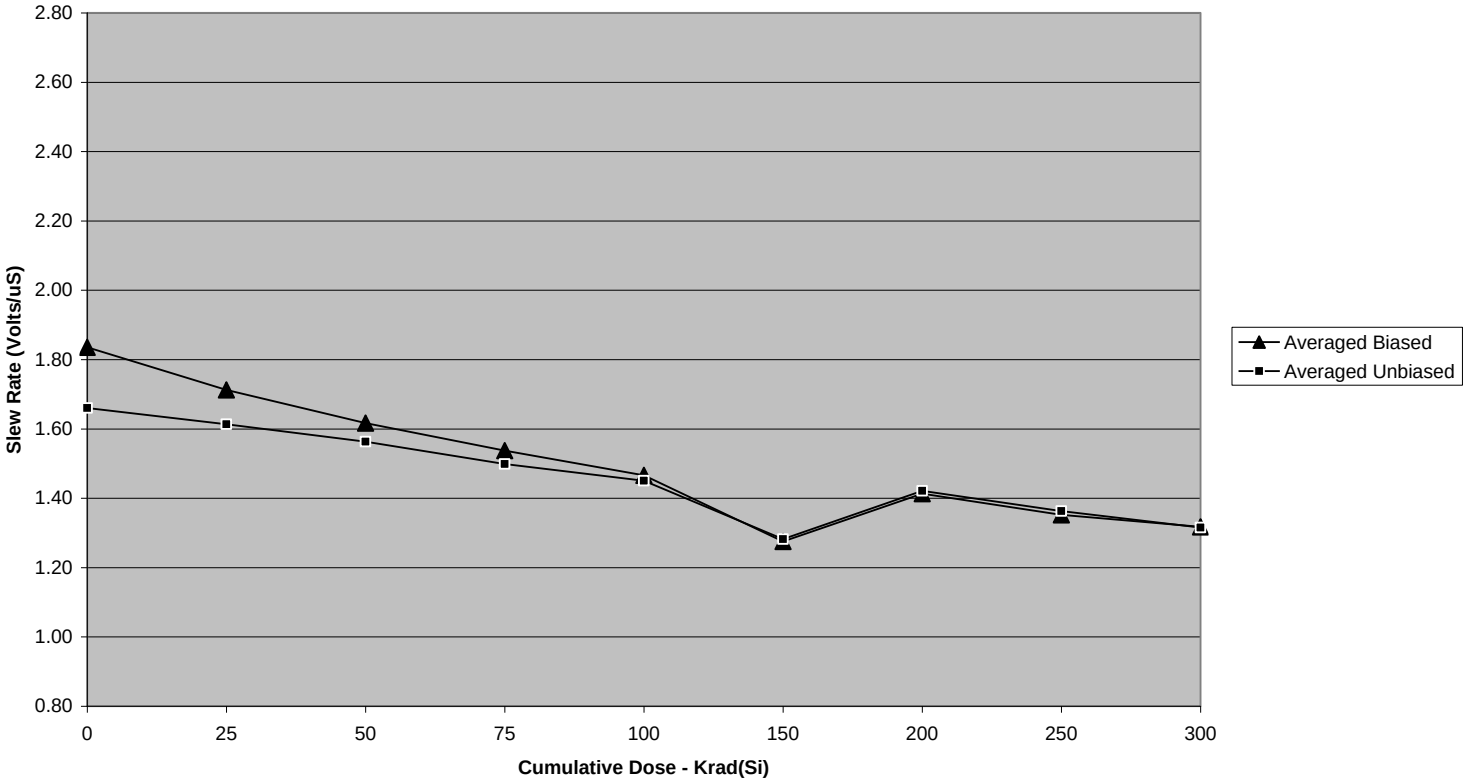
MSK 106RH Positive Short Circuit Current R_{SC} = 5 Ohms



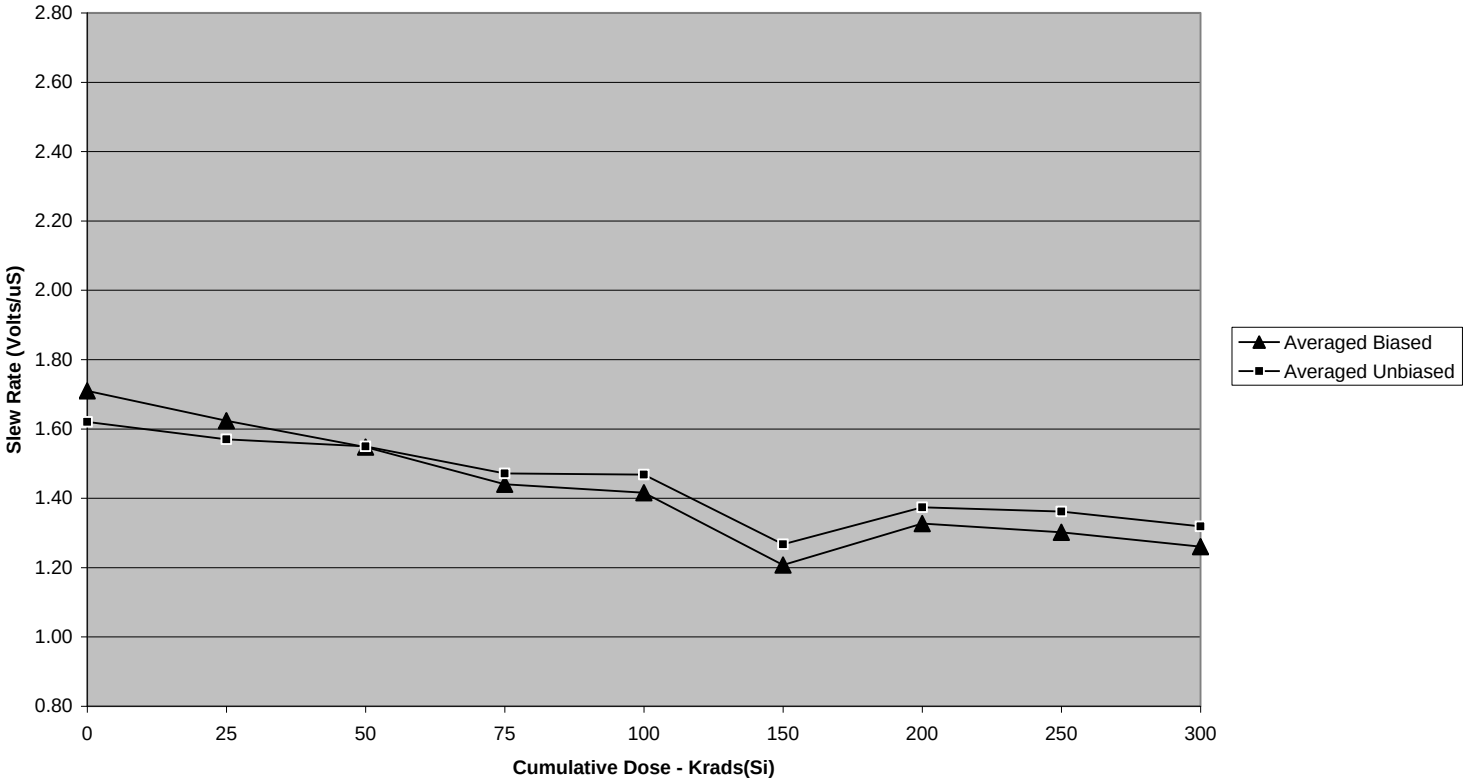
MSK 106RH Negative Short Circuit Current R_{SC} = 5 Ohms



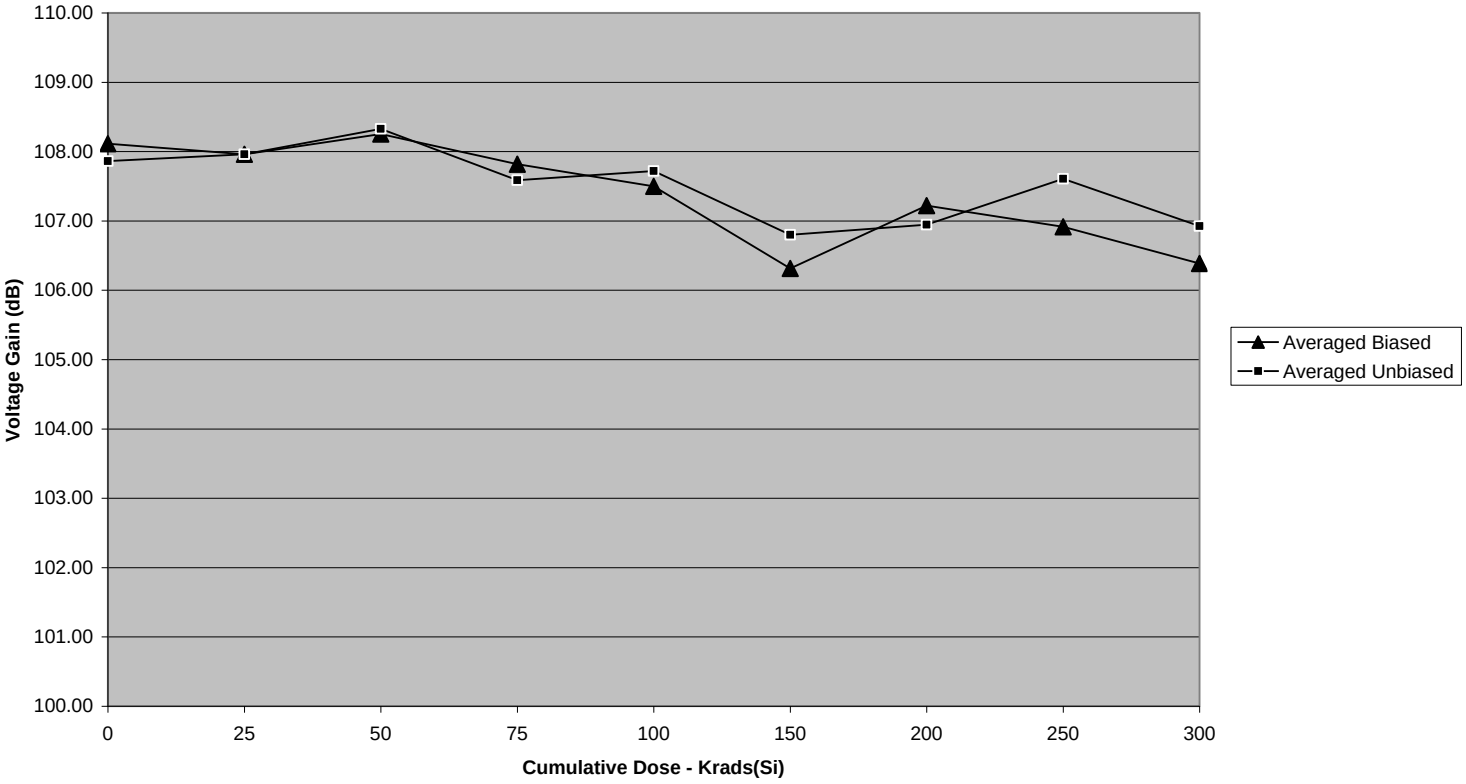
MSK 106RH Slew Rate - Rising Edge



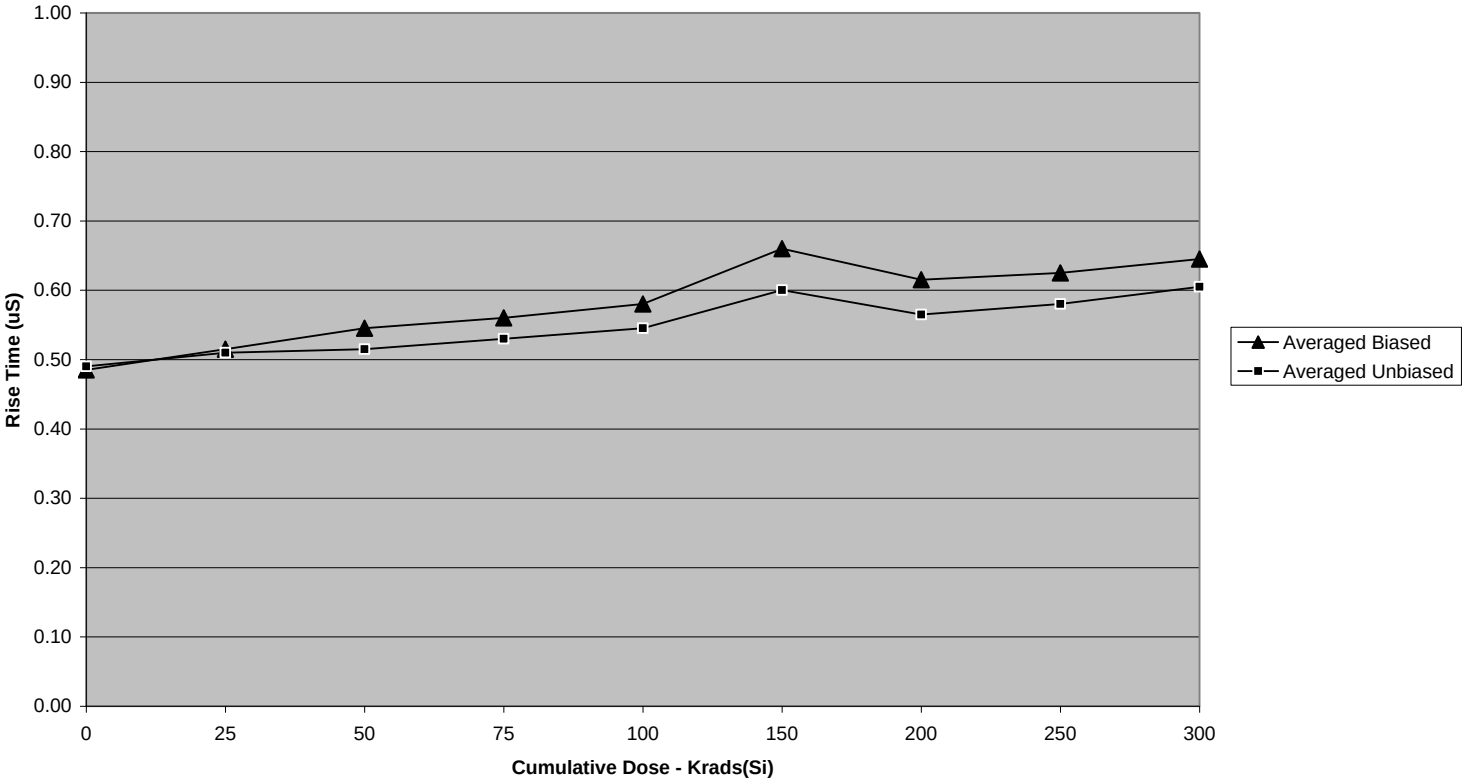
MSK 106RH Slew Rate - Falling Edge



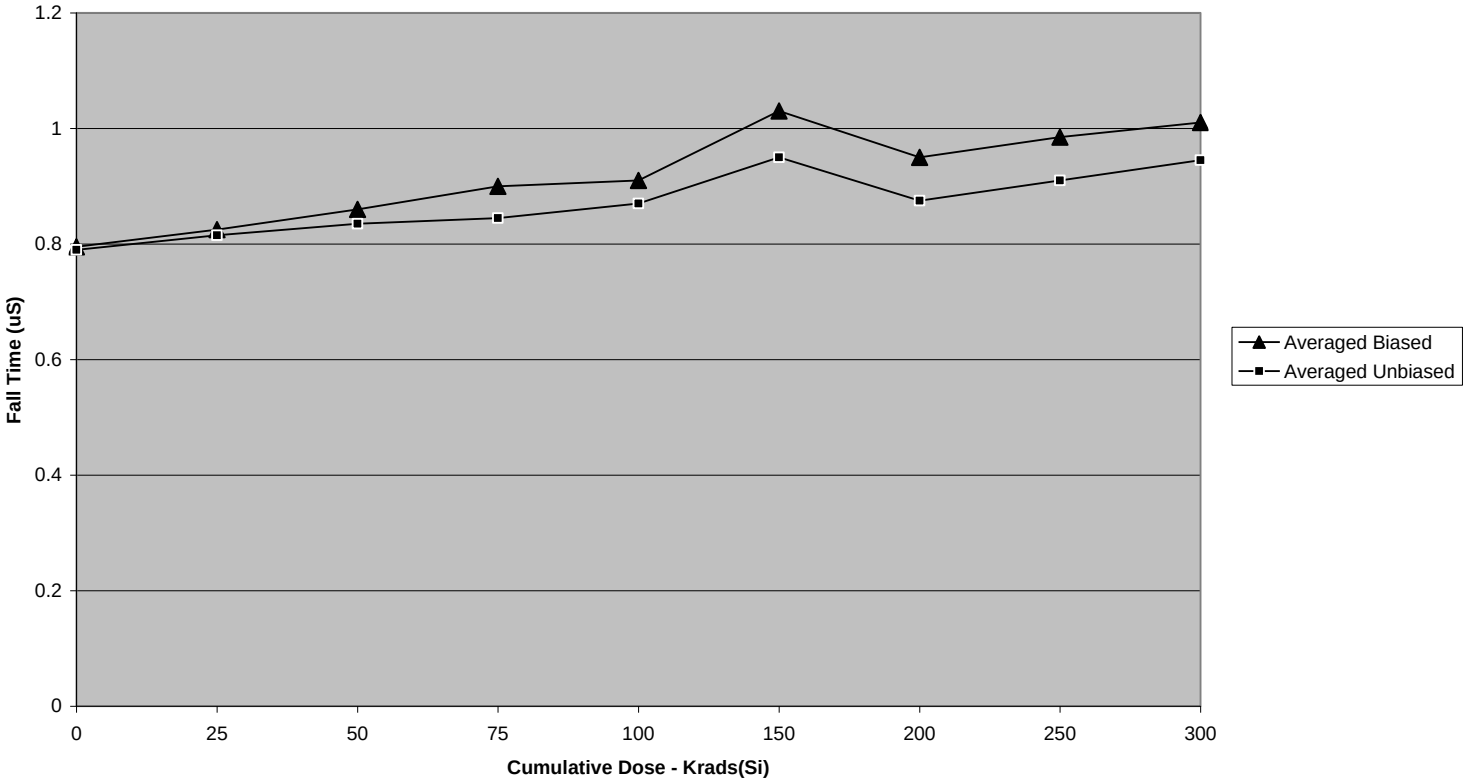
MSK 106RH Voltage Gain



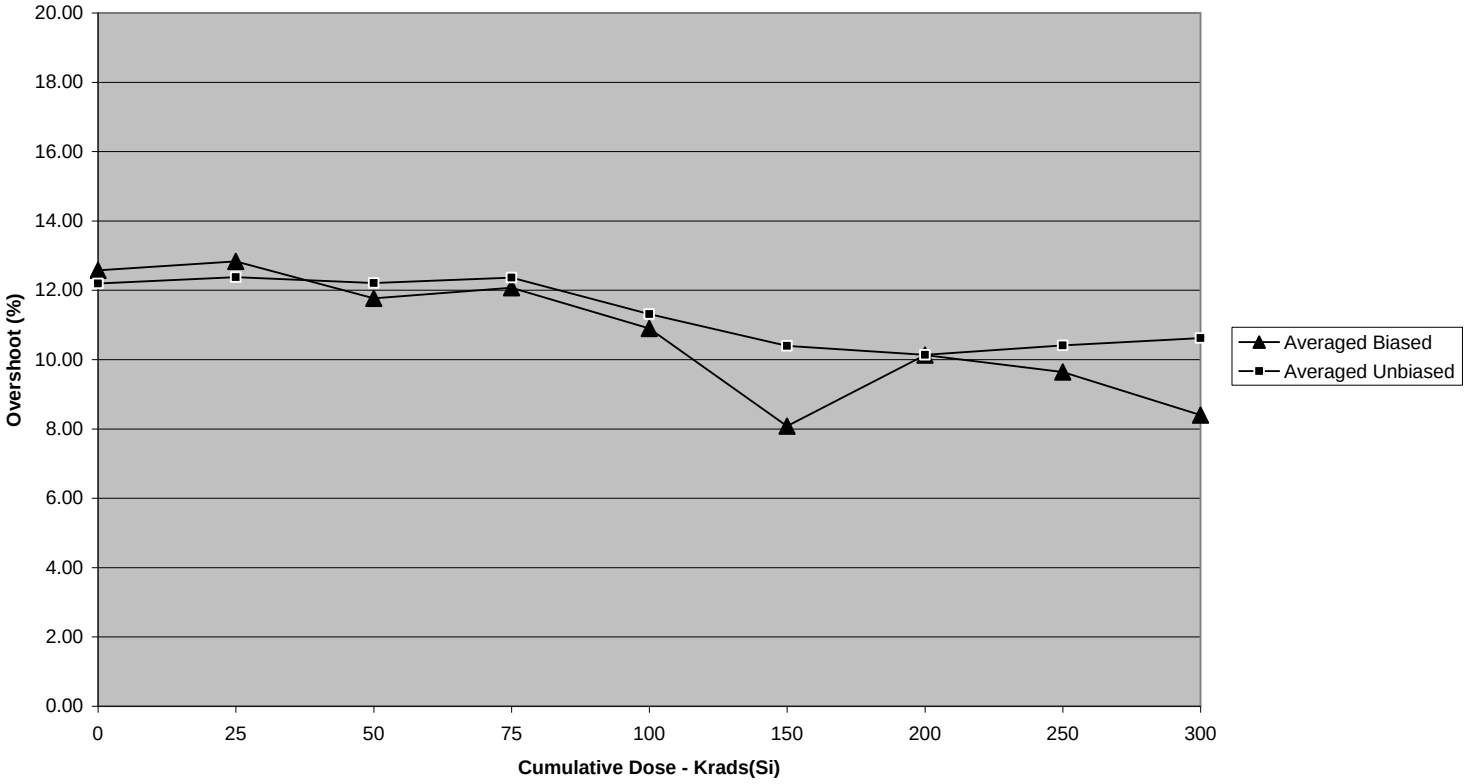
MSK 106RH Rise Time



MSK 106RH Fall Time



MSK 106RH Over Shoot



MSK 106RH Undershoot