

## **Neutron and Total Ionizing Dose Radiation Test Report**

**MSK196RH,  
MSK197RH,  
(MSK496RH)**

### **RAD Hard (QUAD) Precision Rail To Rail Current Sense Amplifier**

May 11, 2012 (TID, First Test, WAFER LOT: WD005335.3 WF#5); Updated February 12, 2013

March 26, 2013 (Neutron Irradiation, WAFER LOT: WD005335.3 WF#5)

Revised May 23, 2017

May 25, 2018 (TID, 2<sup>nd</sup> Test, Wafer Lot: WD34907E.1 Wf#2)

January 19, 2021 (TID, 3<sup>rd</sup> Test, WAFER LOT: WD34907E.1 WF3);

March 23, 2021 (TID, 4<sup>th</sup> Test, WAFER LOT: WD005624.3 WF8);

October 12, 2021 (TID 5<sup>th</sup> Test, Wafer Lot: WP01665E.1 WF2);

J. Saucier

E. Davis

J. Dubose

TTM Technologies – MSK Products

## **I. Introduction:**

The total dose radiation test plan for the MSK197RH was developed to qualify the devices as RAD Hard to 100Krad(Si). The testing was performed beyond 100Krad(Si) to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the device, but simply offers designers insight to the critical parameter-shifts up to the specified total dose level. The MSK196RH, MSK197RH and MSK496RH use the same active components. The data in this report is from direct measurement of the MSK197RH response to irradiation but it is indicative of the response of all devices and is applicable to all.

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 196RH, MSK197RH and MSK 496RH.

## **II. Radiation Source:**

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. The dose rate was determined to be 82.54 Rad(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 burn-in per MIL-STD-883 Method 1015 and were fully screened IAW MIL-PRF-38534 Class K or MIL-PRF-38535 Class V. For test platform verification, one control device was tested at 25°C. Ten 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. Five devices were kept under bias during irradiation. An operating voltage of +30 Volts was used for the bias condition. Five devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and the devices were transported to the MSK automatic electrical test platform. Testing was performed in accordance with the 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. Devices were subjected to subsequent radiation doses within two hours of removal from the radiation field.

## **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 TTM Technologies – MSK Products.

## **V. Summary:**

Based on the test data recorded during radiation testing and statistical analysis, the MSK196RH, MSK197RH and MSK496RH qualify as a 100KRad(Si) radiation hardened devices. Voltage Gain Error 2 ( $V_{s\pm 0V}$ ), Input Offset voltage, PSRR and CMRR exhibited the most significant shift due to irradiation. All other parameters stayed within pre-irradiation specification up to 150KRad(Si).

MSK197RH Biased/Unbiased Dose Rate  
Schedule

Dosimetry Equipment  
Bruker Biospin # 0162

Irradiation Date  
10/12/21

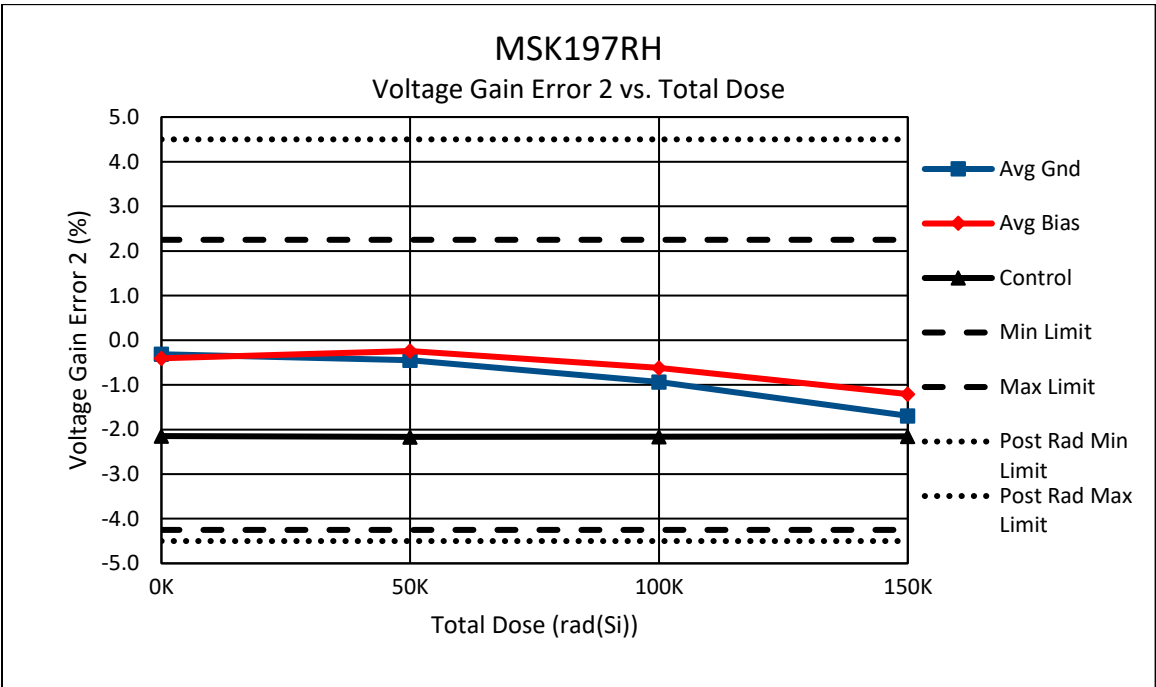
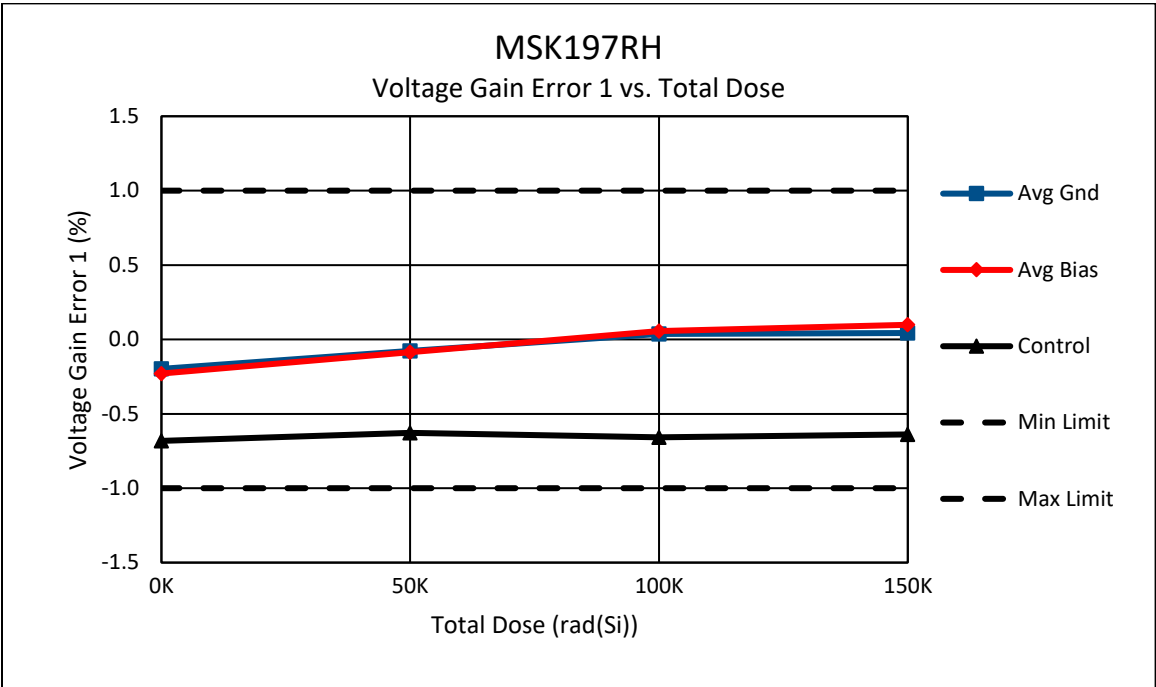
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10:24	51,500	103,000
10:24	51,500	154,500

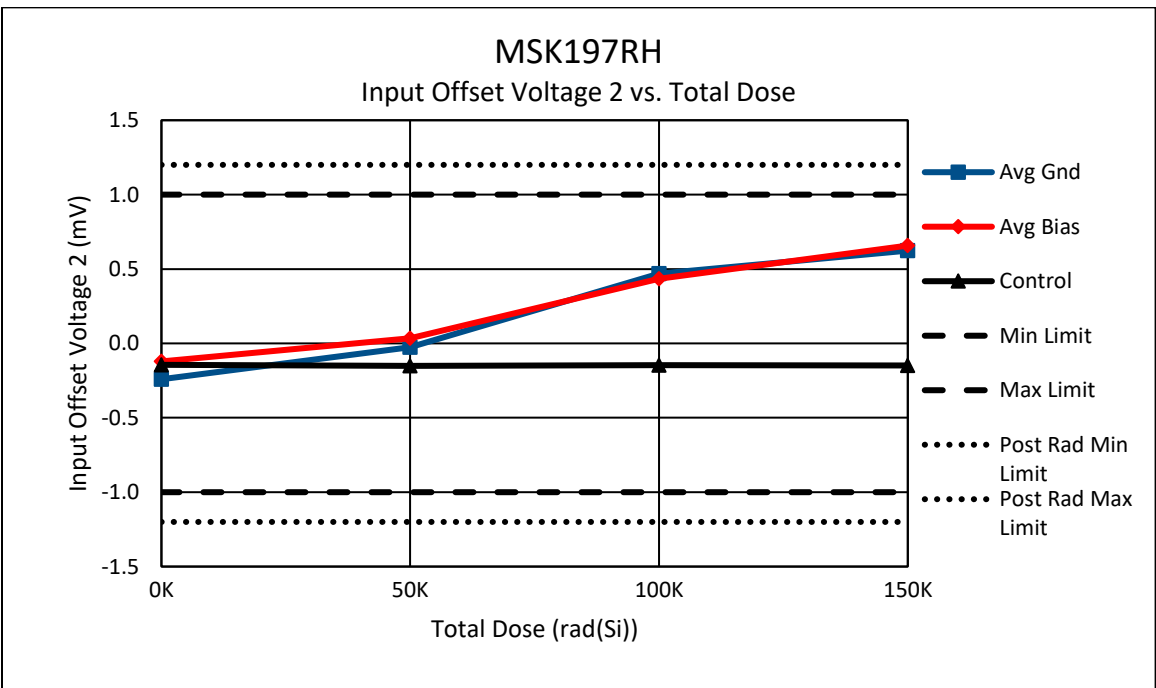
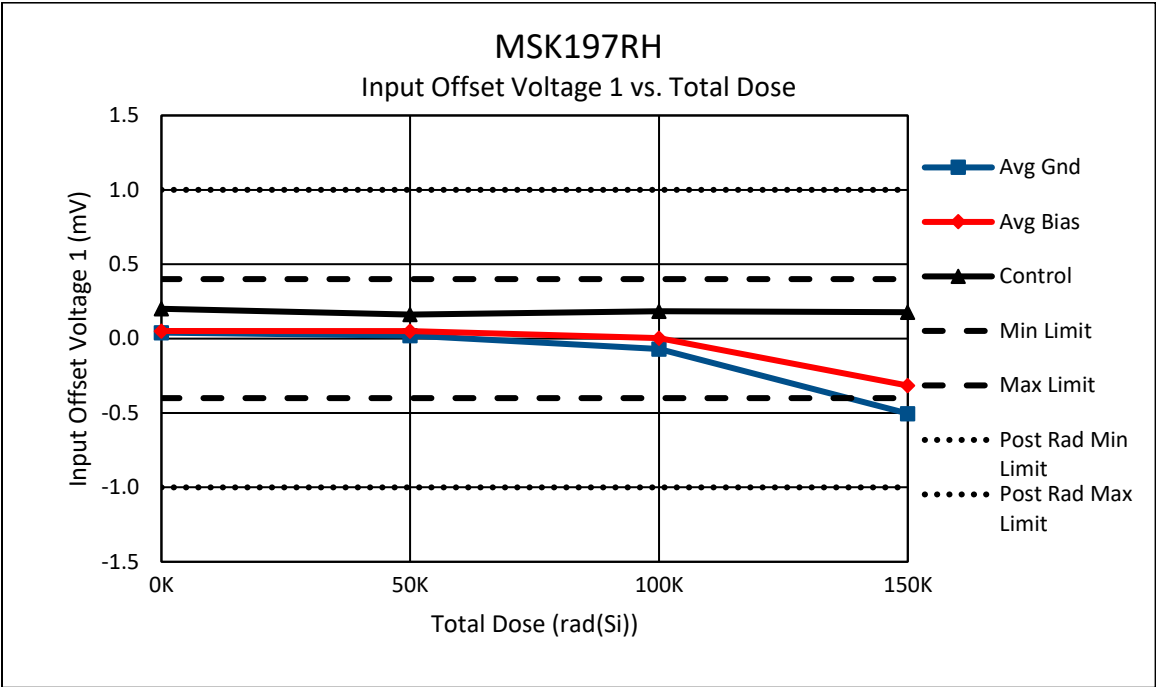
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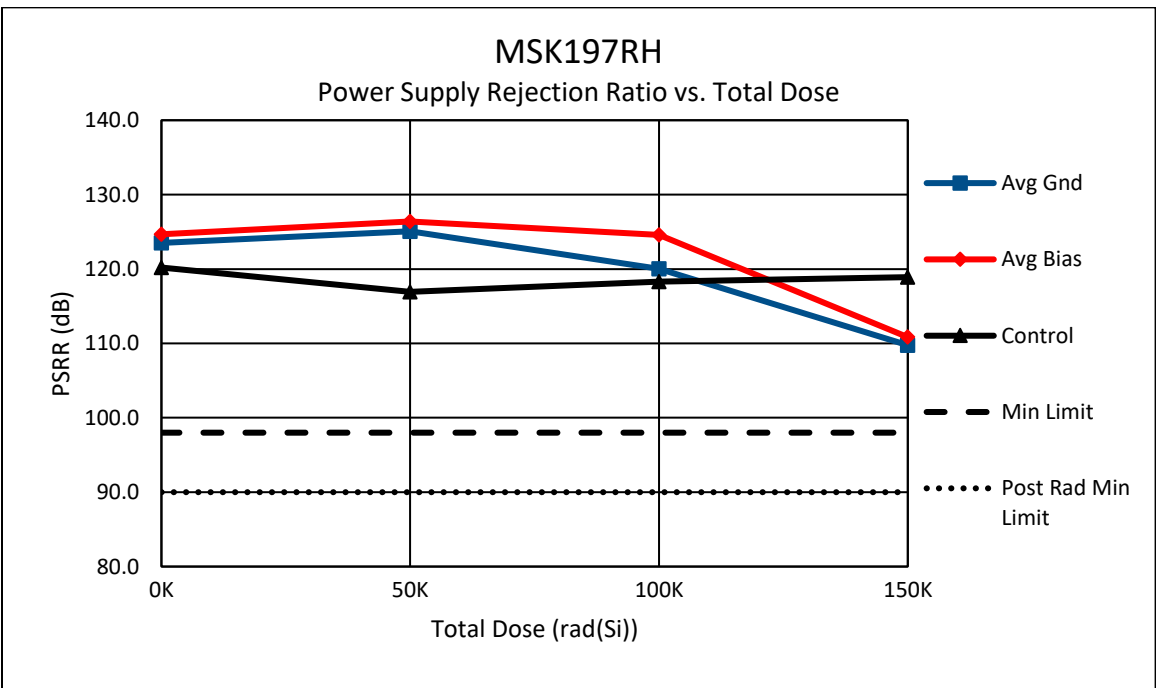
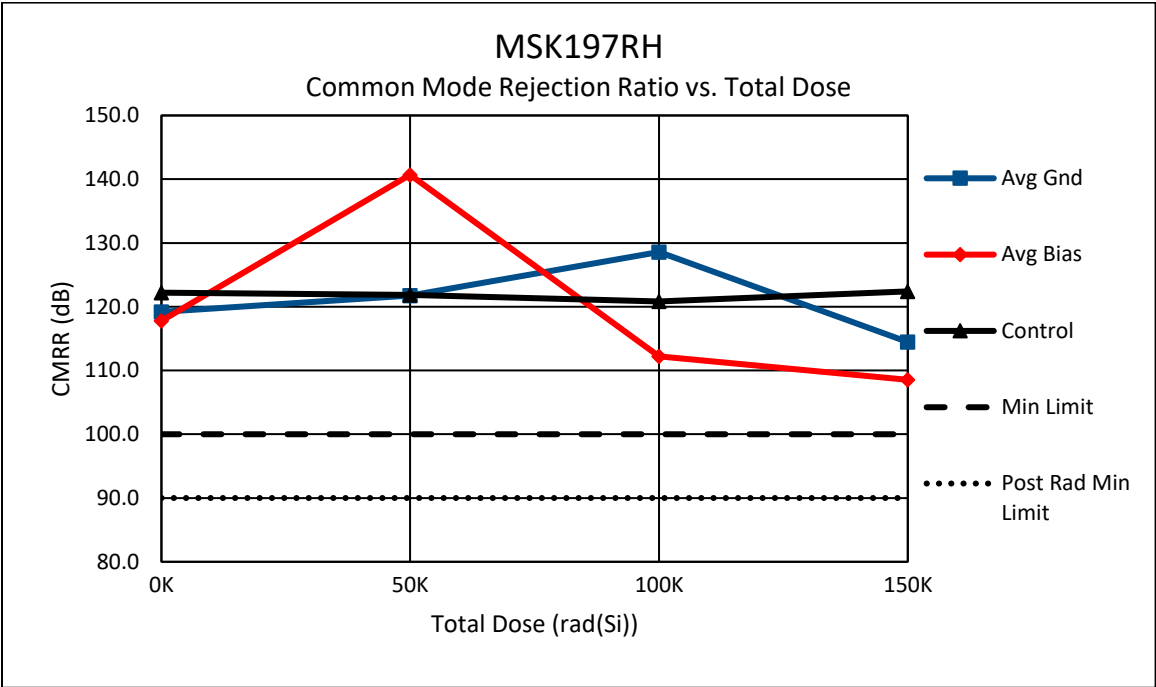
Unbiased S/N – 0080, 0082, 0083, 0084, 0085

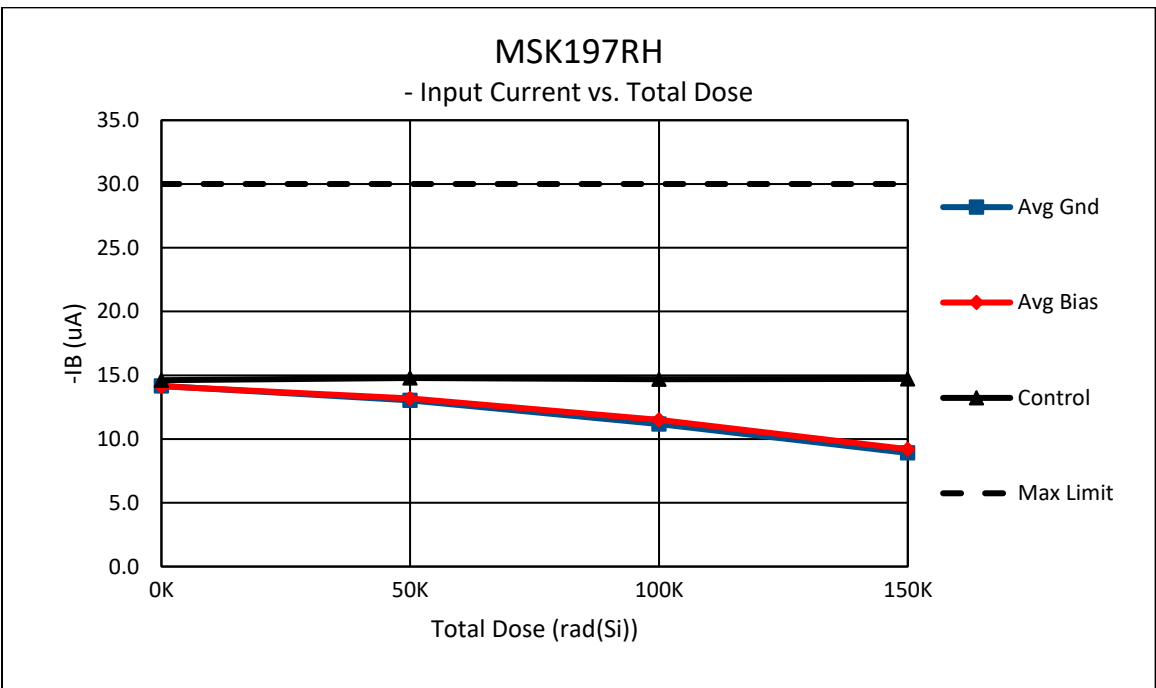
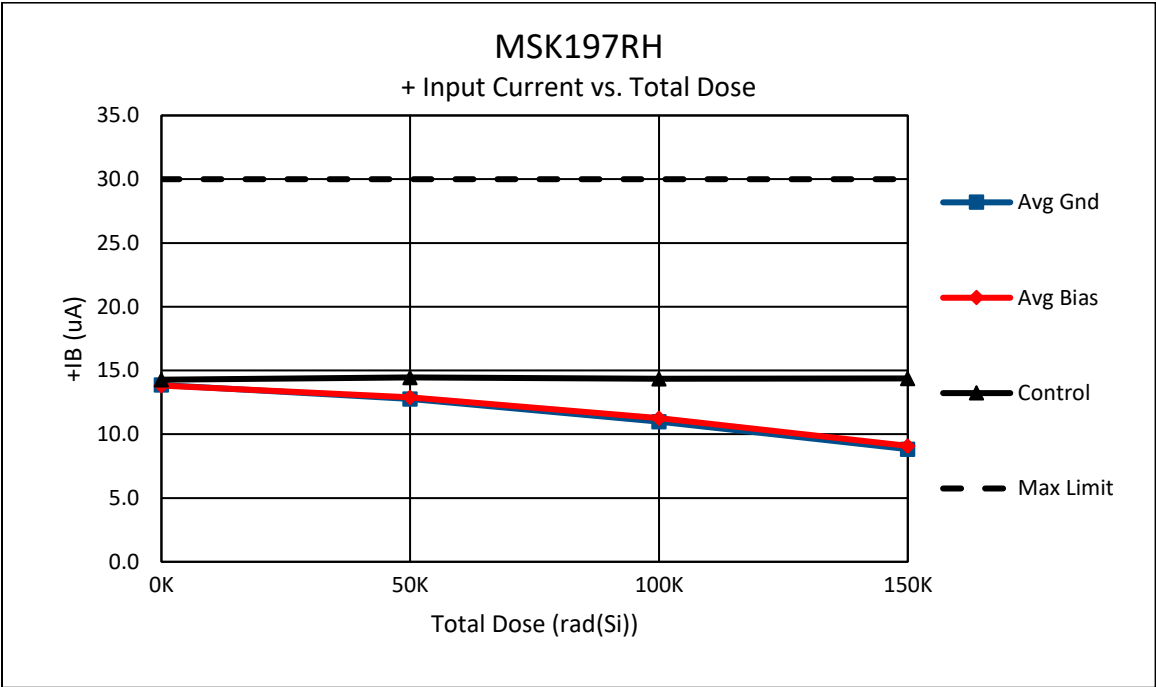
Table 1

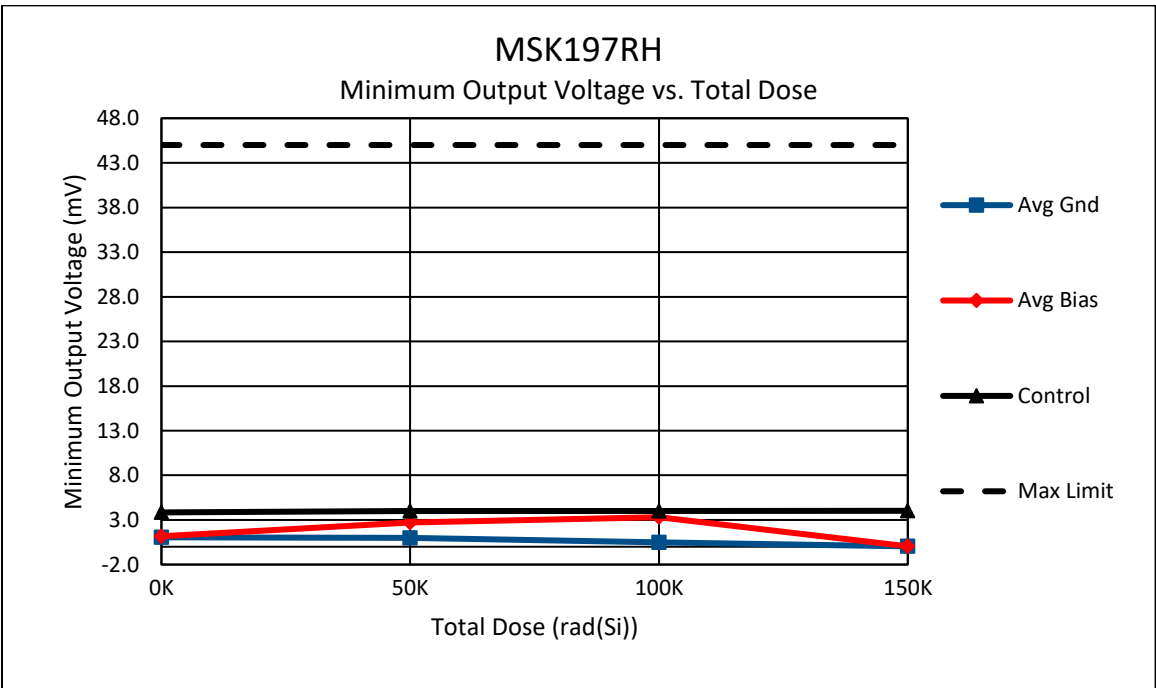
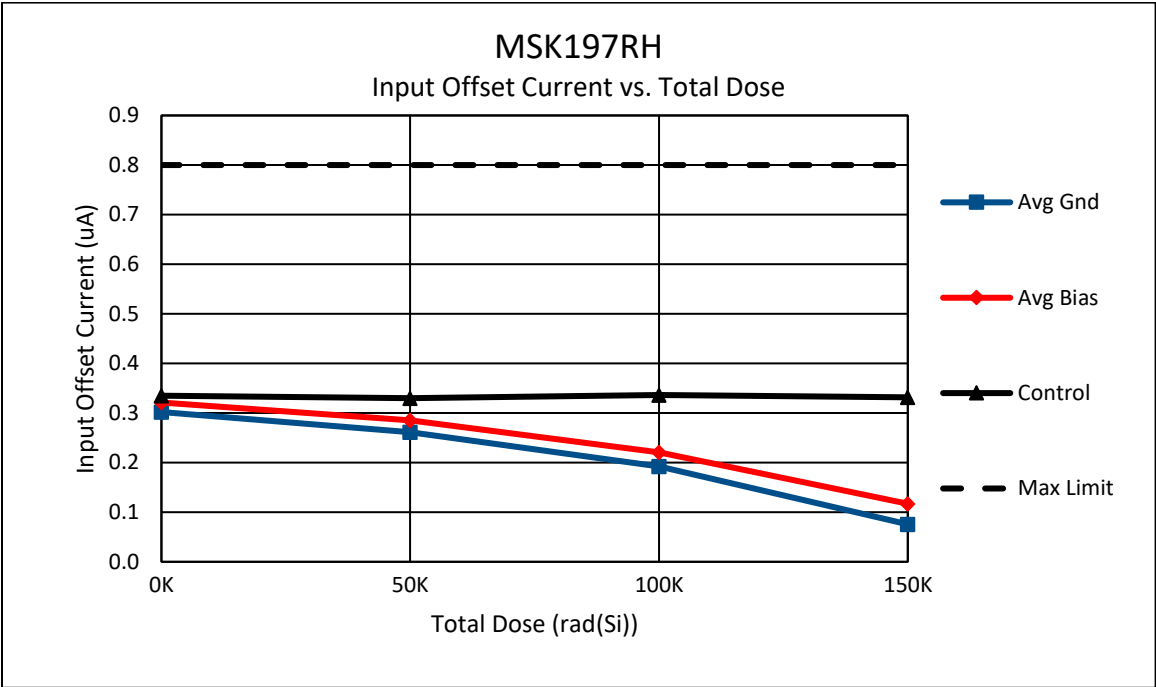
**Dose Time, Incremental Dose and Total Cumulative Dose**



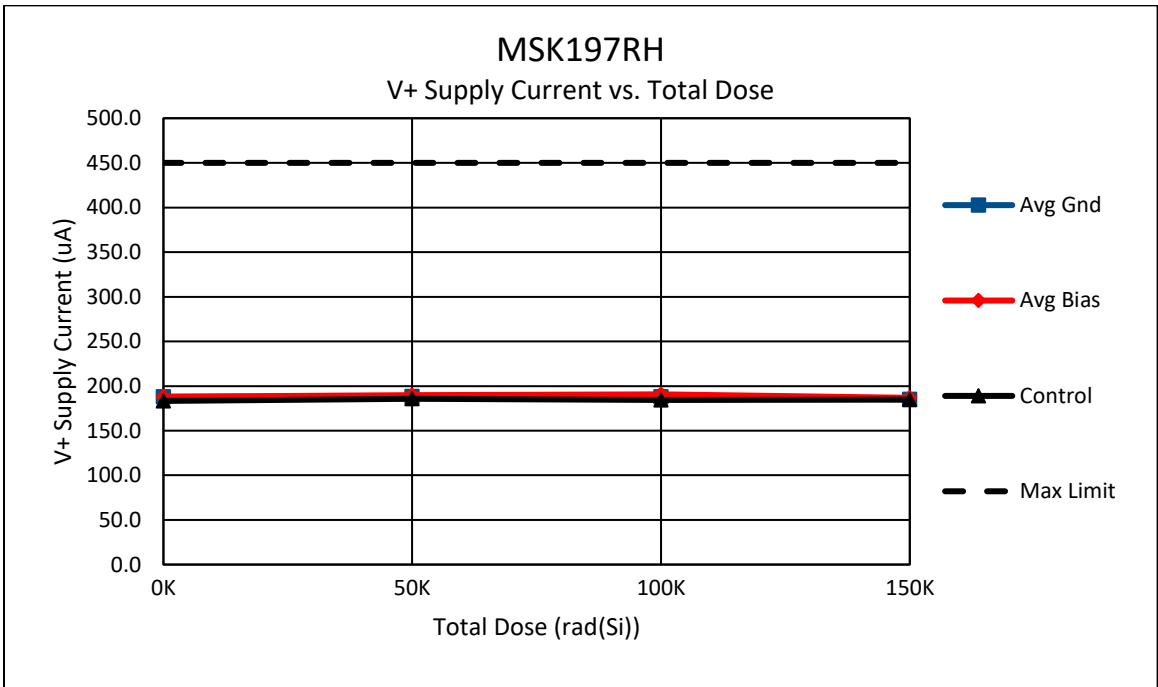
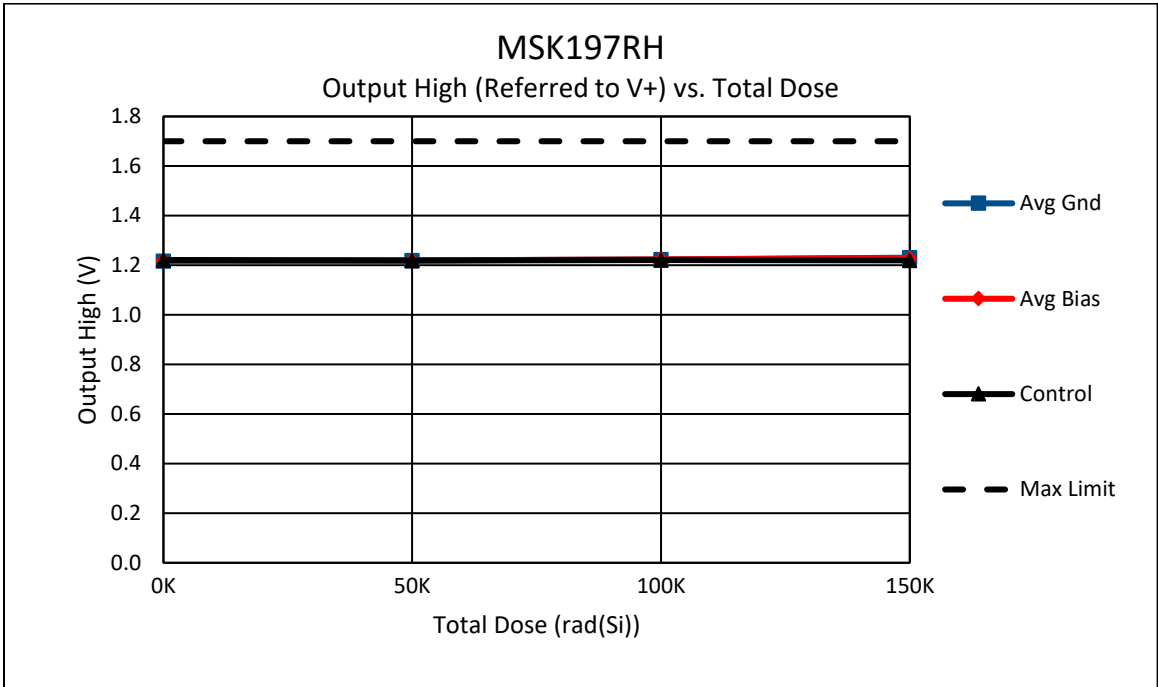












## **Neutron and Total Ionizing Dose Radiation Test Report**

**MSK196RH,  
MSK197RH,  
(MSK496RH)**

### **RAD Hard (QUAD) Precision Rail To Rail Current Sense Amplifier**

May 11, 2012 (TID, First Test, WAFER LOT: WD005335.3 WF#5); Updated February  
12, 2013

March 26, 2013 (Neutron Irradiation, WAFER LOT: WD005335.3 WF#5)  
Revised May 23, 2017

May 25, 2018 (TID, 2<sup>nd</sup> Test, Wafer Lot: WD34907E.1 Wf#2)  
January 19, 2021 (TID, 3<sup>rd</sup> Test, WAFER LOT: WD34907E.1 WF3);  
March 23, 2021 (TID, 4<sup>th</sup> Test, WAFER LOT: WD005624.3 WF8);

J. Saucier  
P. Musil

TTM Technologies

VPT Rad – Radiation Lab & Test Services

## **I. Introduction:**

The total dose radiation test plan for the MSK197RH was developed to qualify the devices as RAD Hard to 100Krad(Si). The testing was performed beyond 100Krad(Si) to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the device, but simply offers designers insight to the critical parameter-shifts up to the specified total dose level. The MSK196RH, MSK197RH and MSK496RH use the same active components. The data in this report is from direct measurement of the MSK197RH response to irradiation but it is indicative of the response of all devices and is applicable to all.

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 196RH, MSK197RH and MSK 496RH.

## **II. Radiation Source:**

Total dose was performed at VPT Rad, Chelmsford Massachusetts, using a cobalt 60 radiation source. The dose rate was determined to be 116 Rad(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 burn-in per MIL-STD-883 Method 1015 and were fully screened IAW MILPRF-38534 Class K or MIL-PRF-38535 Class V. For test platform verification, one control device was tested at 25 ° C. Ten 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. Five devices were kept under bias during irradiation. An operating voltage of +30 Volts was used for the bias condition. Five devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and the devices were transported to the MSK automatic electrical test platform. Testing was performed in accordance with the 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. Devices were subjected to subsequent radiation doses within two hours of removal from the radiation field.

## **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 TTM Technologies – MSK Products.

## **V. Summary:**

Based on the test data recorded during radiation testing and statistical analysis, the MSK196RH, MSK197RH and MSK496RH qualify as a 100KRad(Si) radiation hardened devices. Voltage Gain Error 2 ( $V_{s+}=0V$ ), Input Offset voltage, PSRR and CMRR exhibited the most significant shift due to irradiation. All other parameters stayed within pre-irradiation specification up to 150KRad(Si).

MSK197RH Biased/Unbiased Dose Rate Schedule
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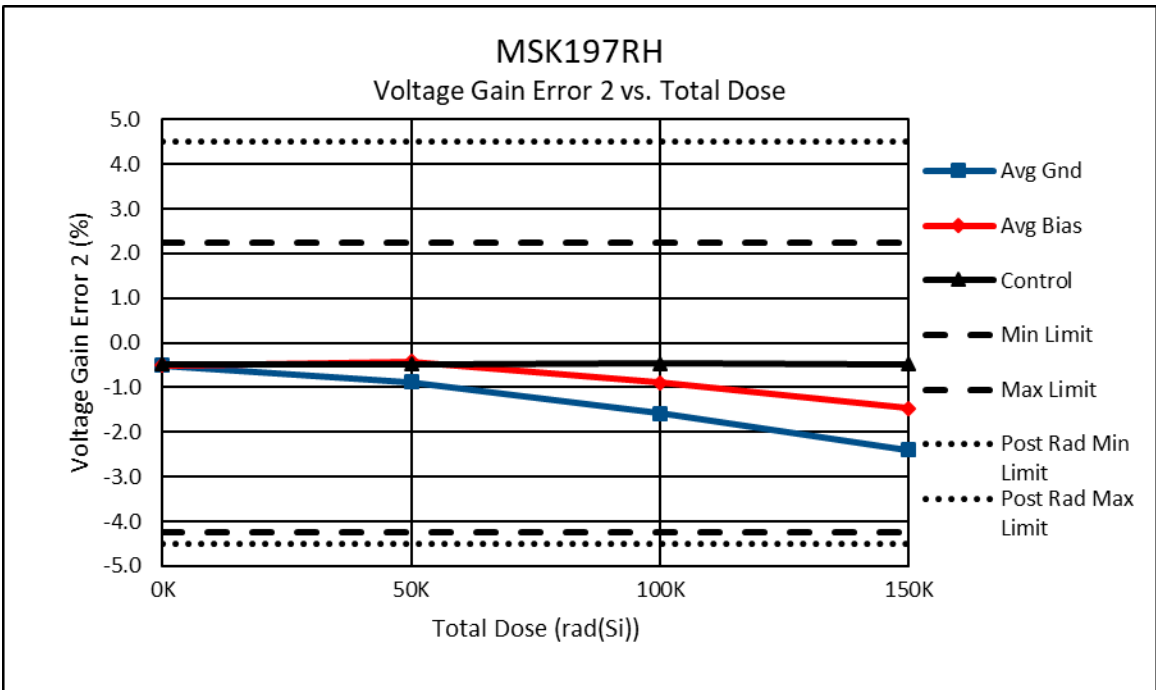
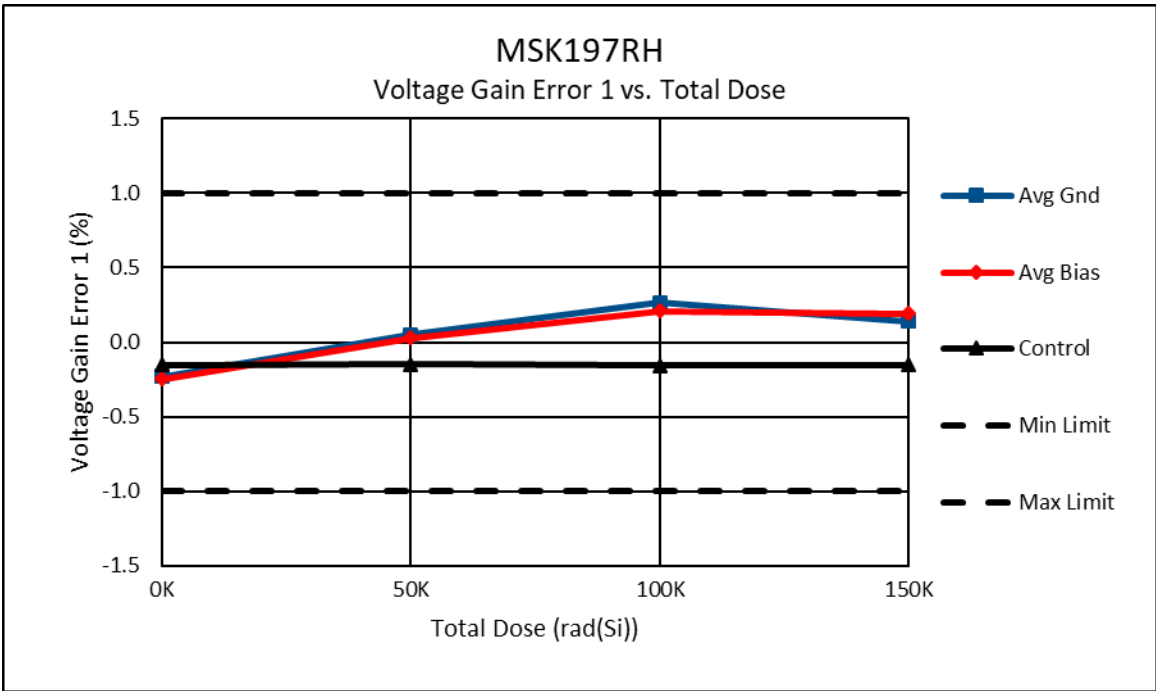
Dosimetry Equipment
Bruker Biospin # SC0424

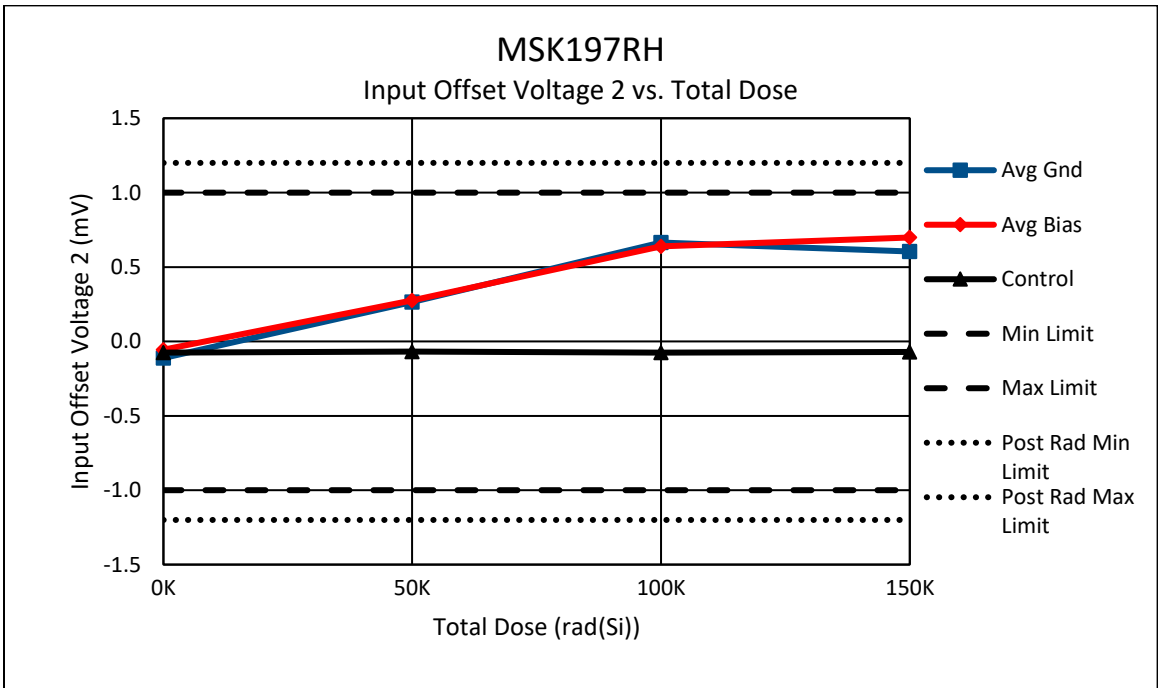
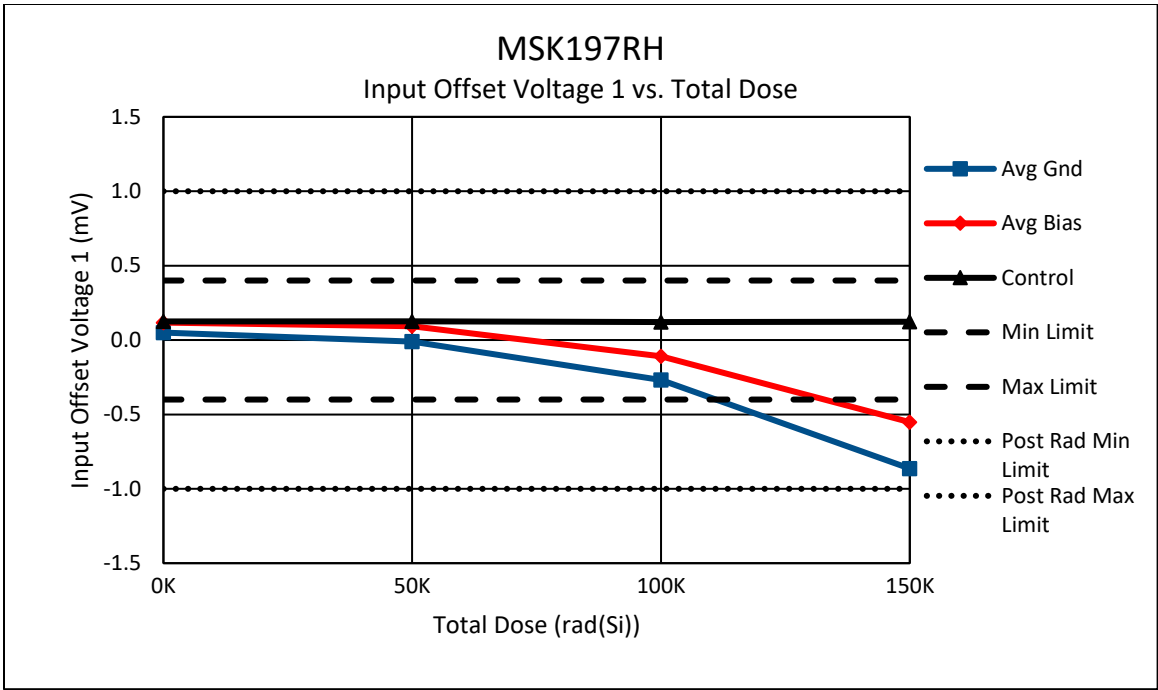
Irradiation Date
3/23/21

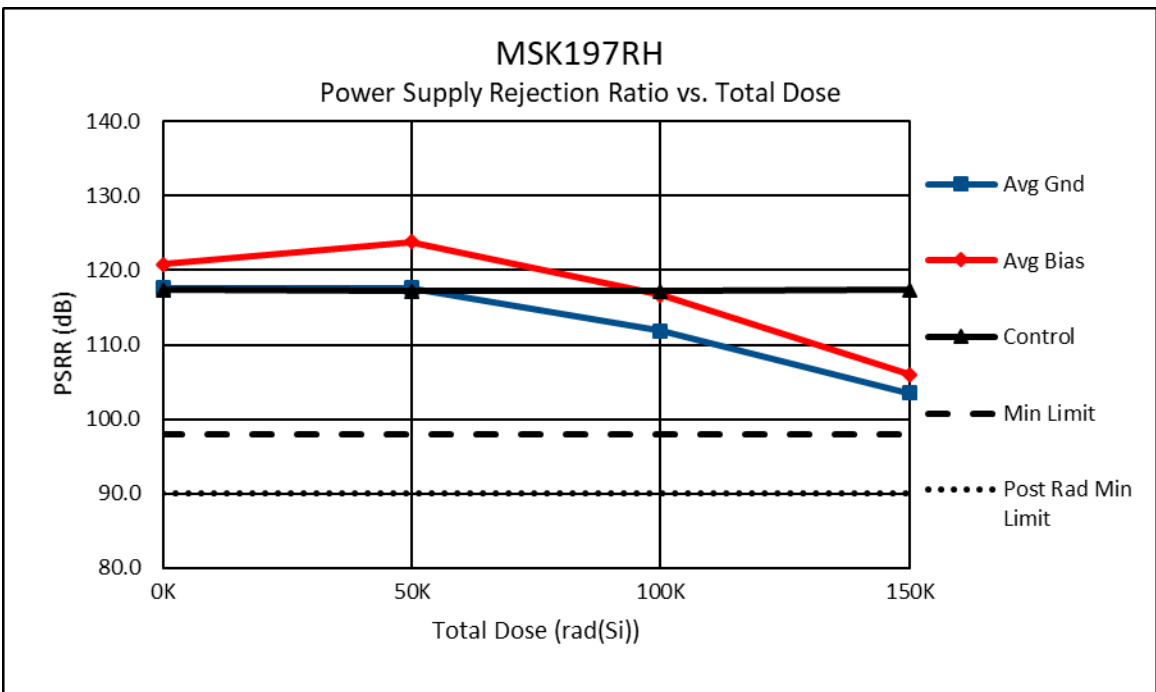
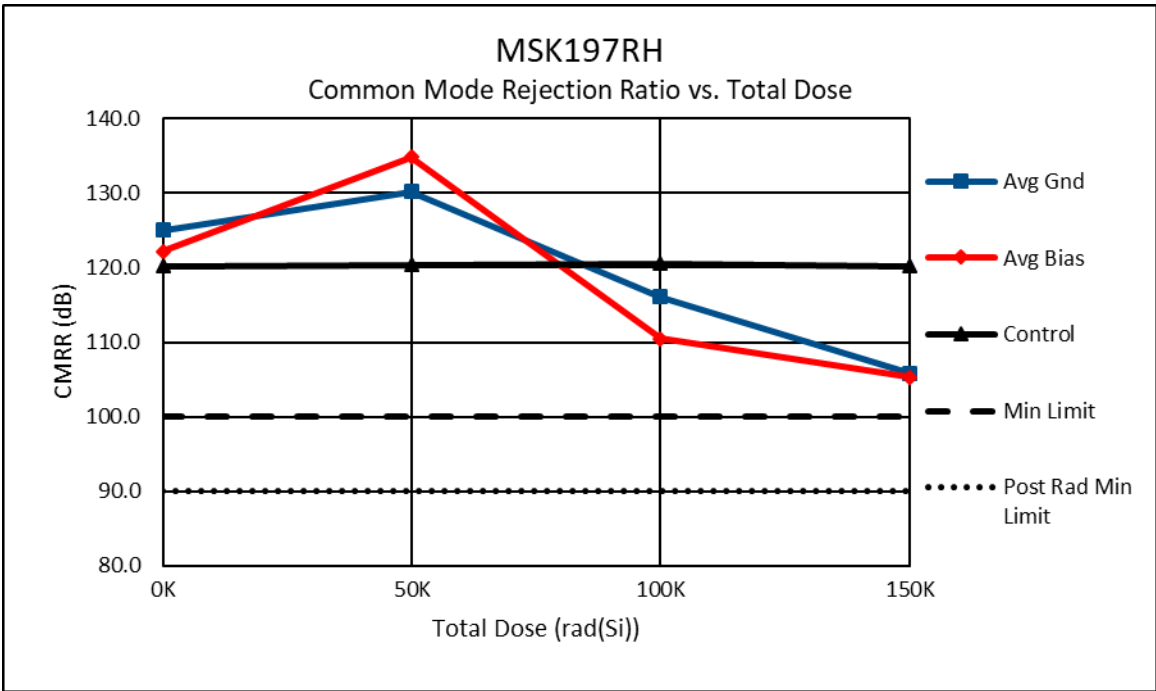
Exposure Length (min:sec)	Incremental Dose rads(Si)	Cumulative Dose rads(Si)
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7:24	51,504	103,008
7:24	51,504	154,512

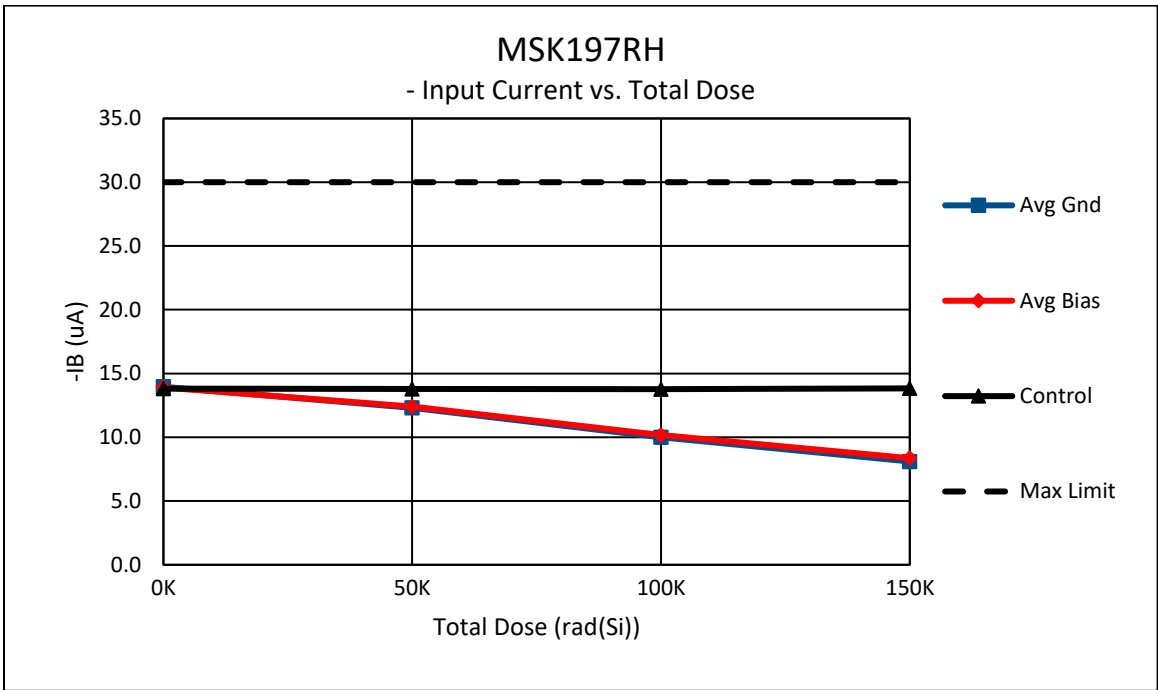
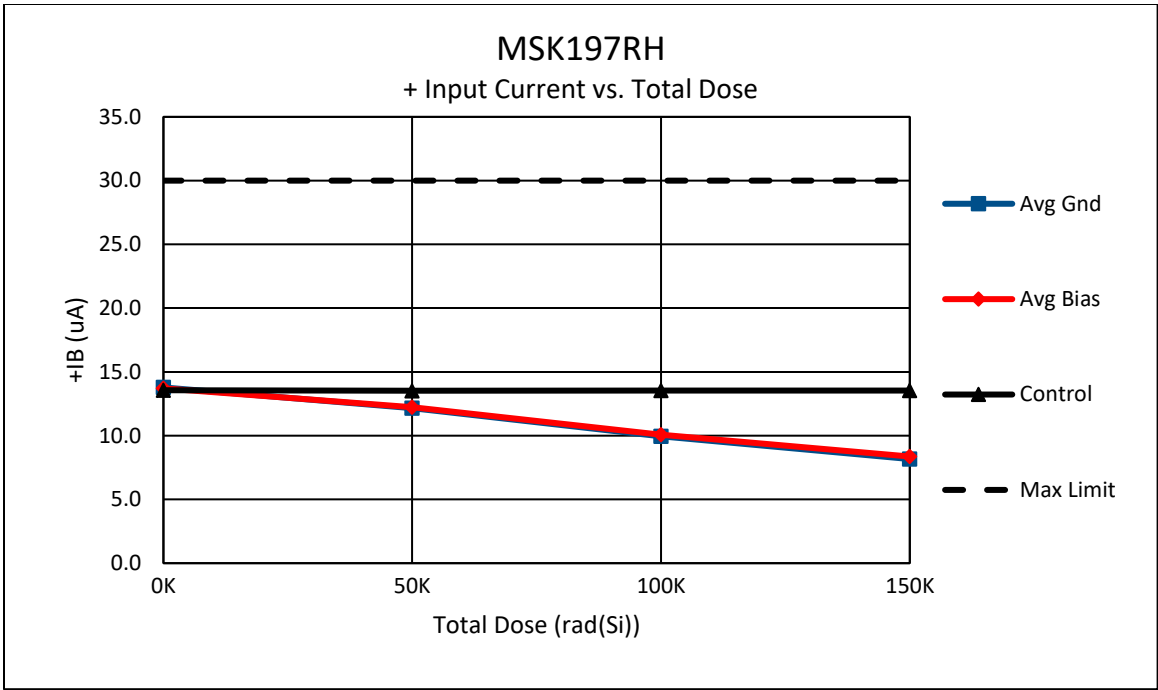
Biased S/N – 0052, 0053, 0054, 0055, 0056
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Unbiased S/N – 0057, 0058, 0059, 0060, 0061
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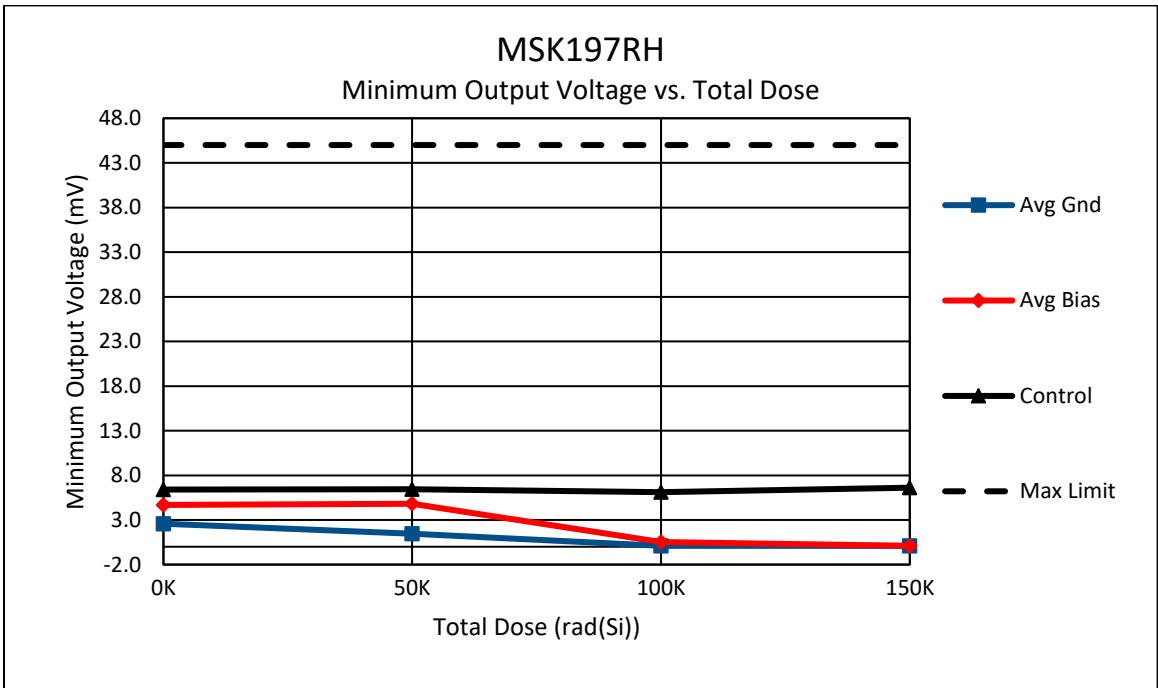
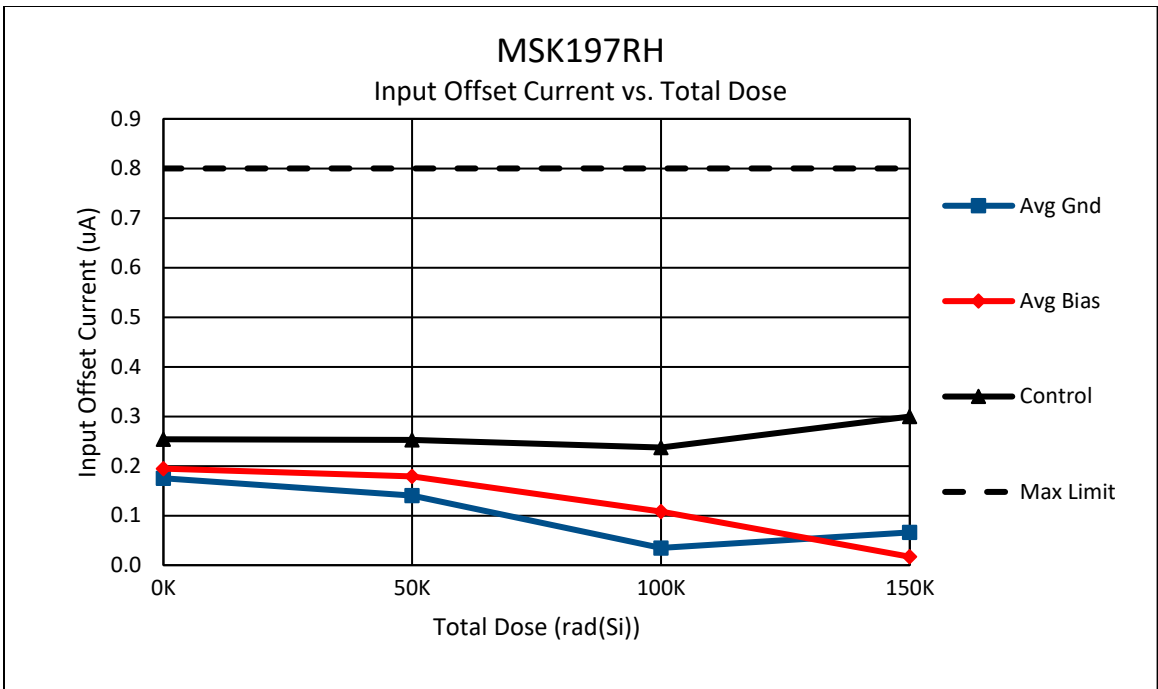


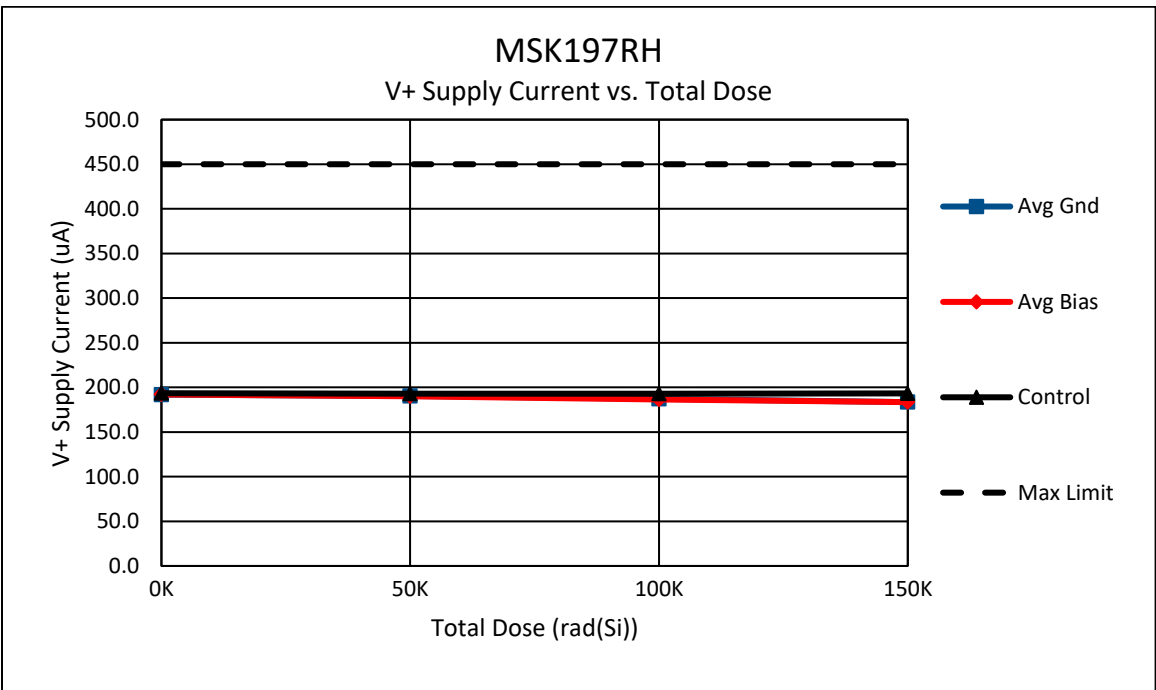
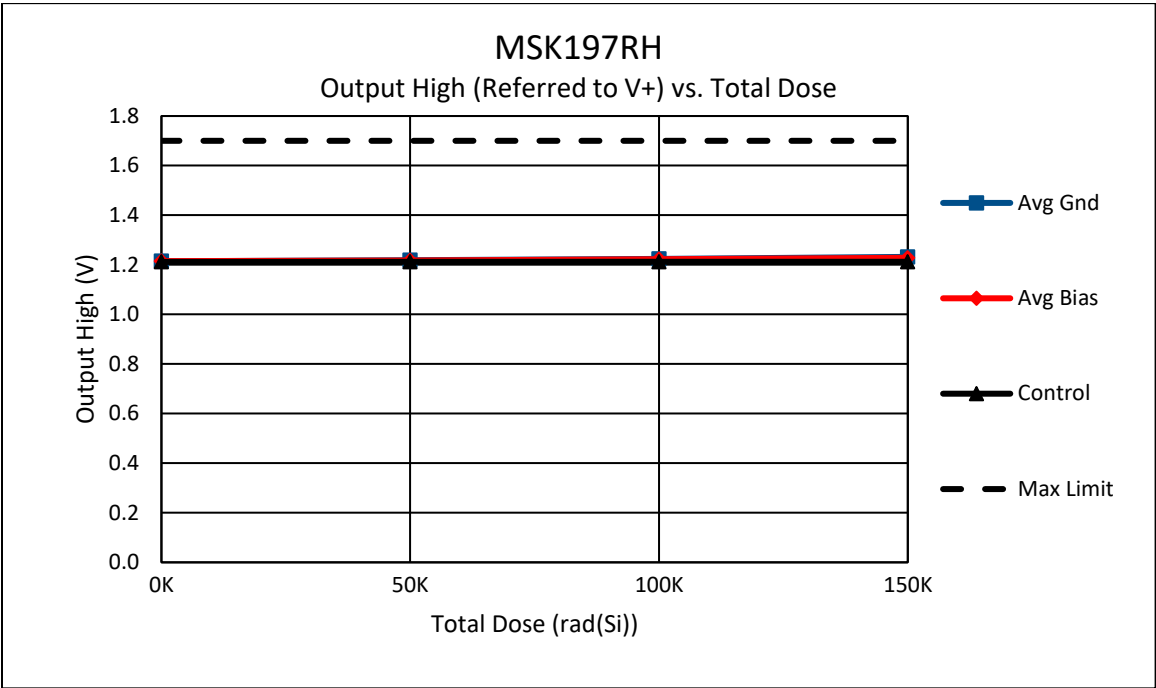












## **Neutron and Total Ionizing Dose Radiation Test Report**

**MSK196RH,  
MSK197RH,  
(MSK496RH)**

**RAD Hard (QUAD) Precision Rail To Rail Current Sense Amplifier**

May 11, 2012 (TID, First Test, WAFER LOT: WD005335.3 WF#5); Updated February 12, 2013

March 26, 2013 (Neutron Irradiation, WAFER LOT: WD005335.3 WF#5)

Revised May 23, 2017

May 25, 2018 (TID, 2<sup>nd</sup> Test Wafer Lot: WD34907E.1 Wf#2)

N. Kresse  
F. Freytag

Anaren, Inc. – MSK Products

## I. Introduction:

The total dose radiation test plan for the MSK197RH was developed to qualify the devices as RAD Hard to 100Krad(Si). The testing was performed beyond 100Krad(Si) to show trends in device performance as a function of total dose. The test does not classify maximum radiation tolerance of the device, but simply offers designers insight to the critical parameter-shifts up to the specified total dose level. The MSK196RH, MSK197RH and MSK496RH use the same active components. The data in this report is from direct measurement of the MSK197RH response to irradiation but it is indicative of the response of all devices and is applicable to all.

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 196RH, MSK197RH and MSK 496RH.

## II. Radiation Source:

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. The dose rate was determined to be 121.3 Rad(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 burn-in per MIL-STD-883 Method 1015 and were fully screened IAW MIL-PRF-38534 Class K or MIL-PRF-38535 Class V. For test platform verification, one control device was tested at 25°C. Ten 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. Five devices were kept under bias during irradiation. An operating voltage of +30 Volts was used for the bias condition. Five devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and the devices were transported to the MSK automatic electrical test platform. Testing was performed in accordance with the 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. Devices were subjected to subsequent radiation doses within two hours of removal from the radiation field.

## 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:

Based on the test data recorded during radiation testing and statistical analysis, the MSK197RH, MSK197RH and MSK496RH qualify as a 100KRad(Si) radiation hardened devices. Voltage Gain Error 2 ( $V_s \neq 0V$ ), Input Offset voltage, PSRR and CMRR exhibited the most significant shift due to irradiation. All other parameters stayed within pre-irradiation specification up to 150KRad(Si).

MSK197VRH Biased/Unbiased Dose Rate  
Schedule

Dosimetry Equipment  
Bruker Biospin # 0162

Irradiation Date  
5/25/18

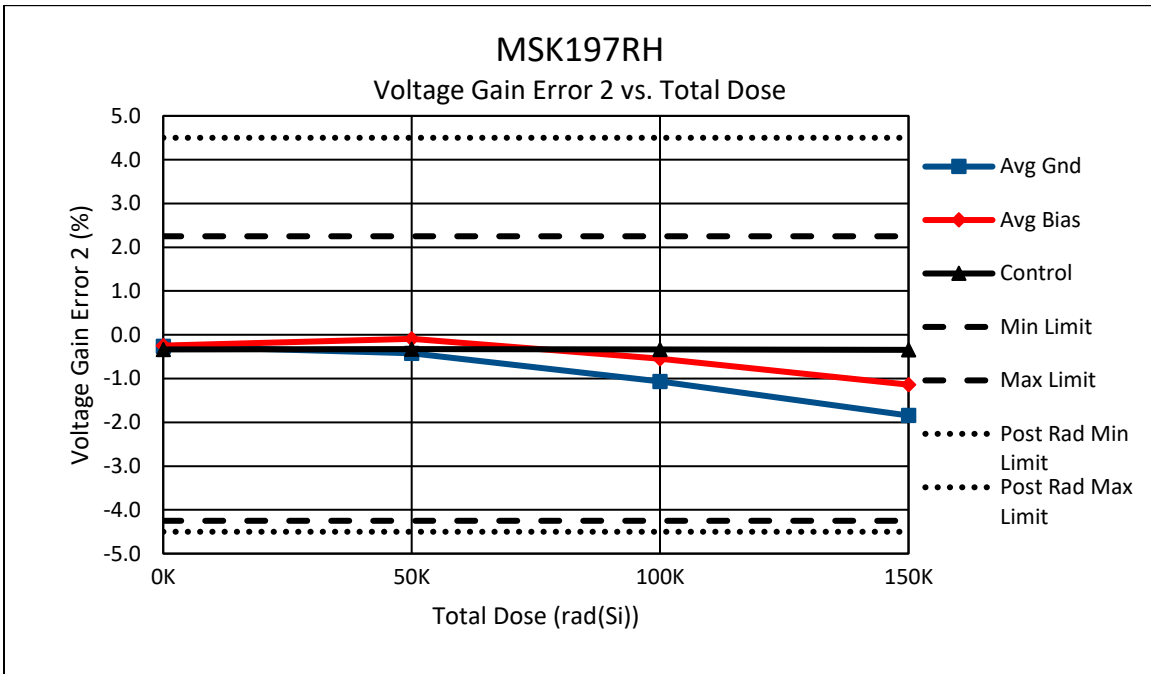
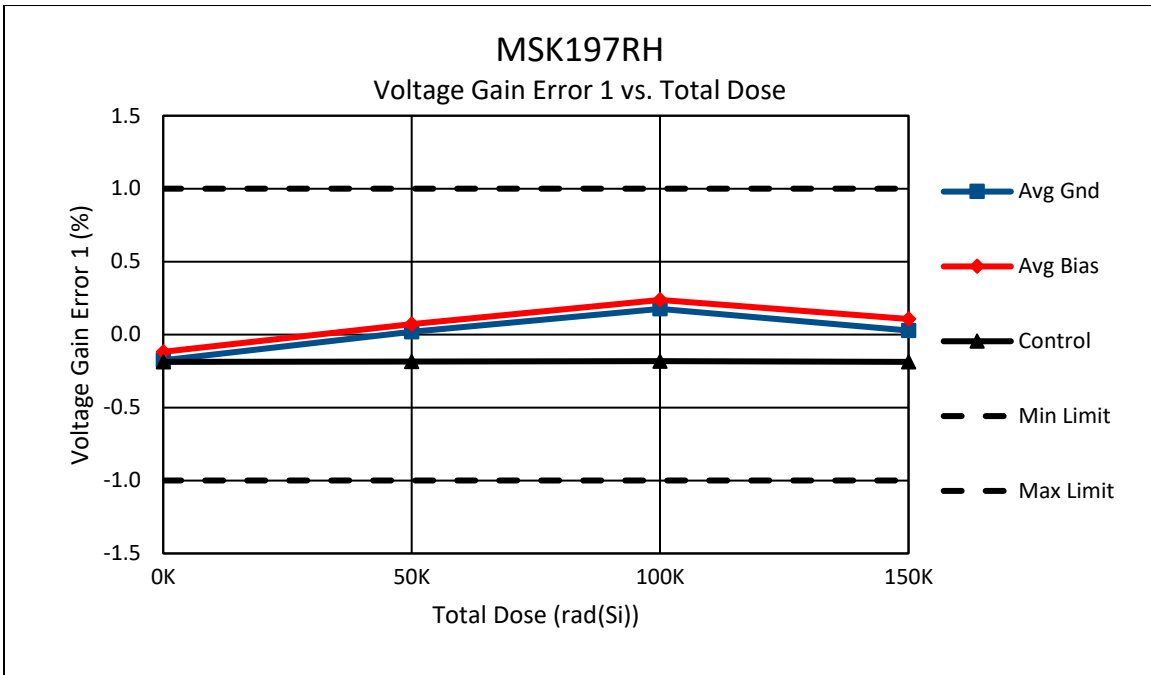
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7:05	51,500	103,00
7:05	51,500	154,500

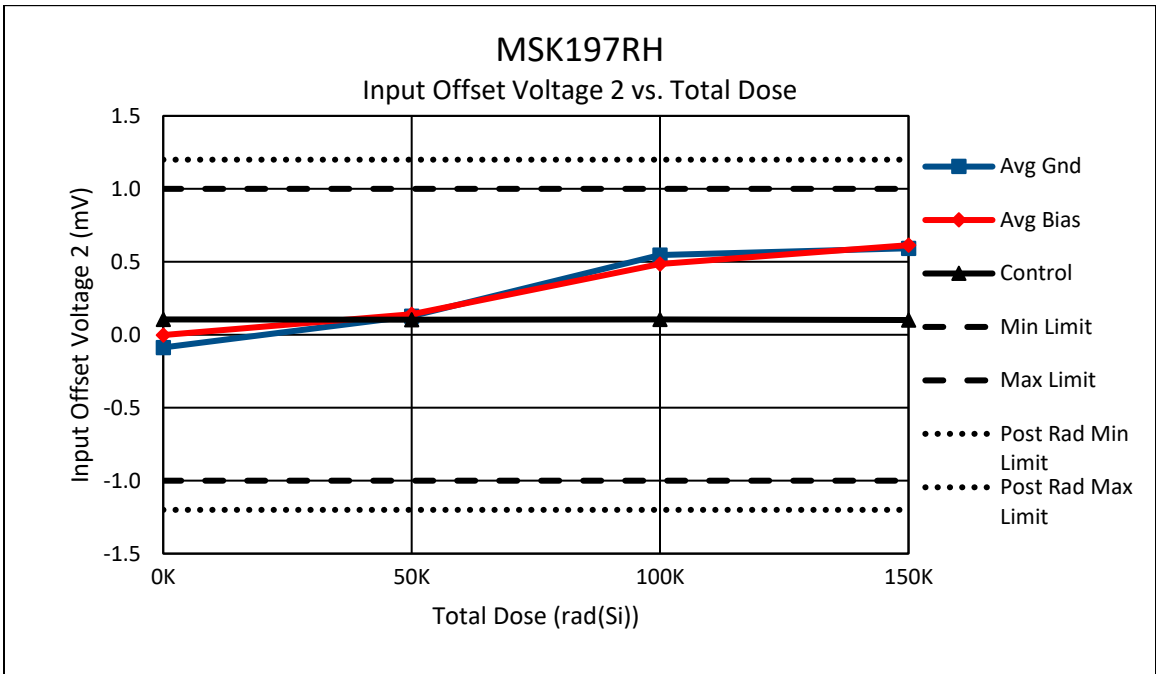
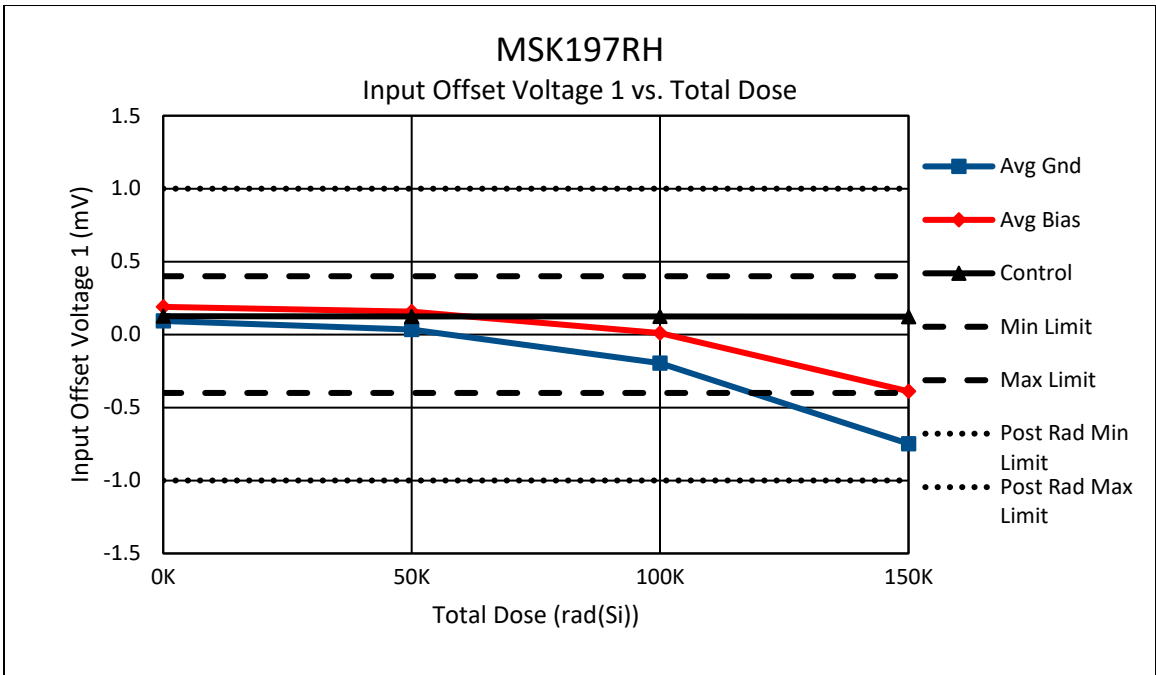
Biased S/N – 0002, 0003, 0004, 0005, 0006

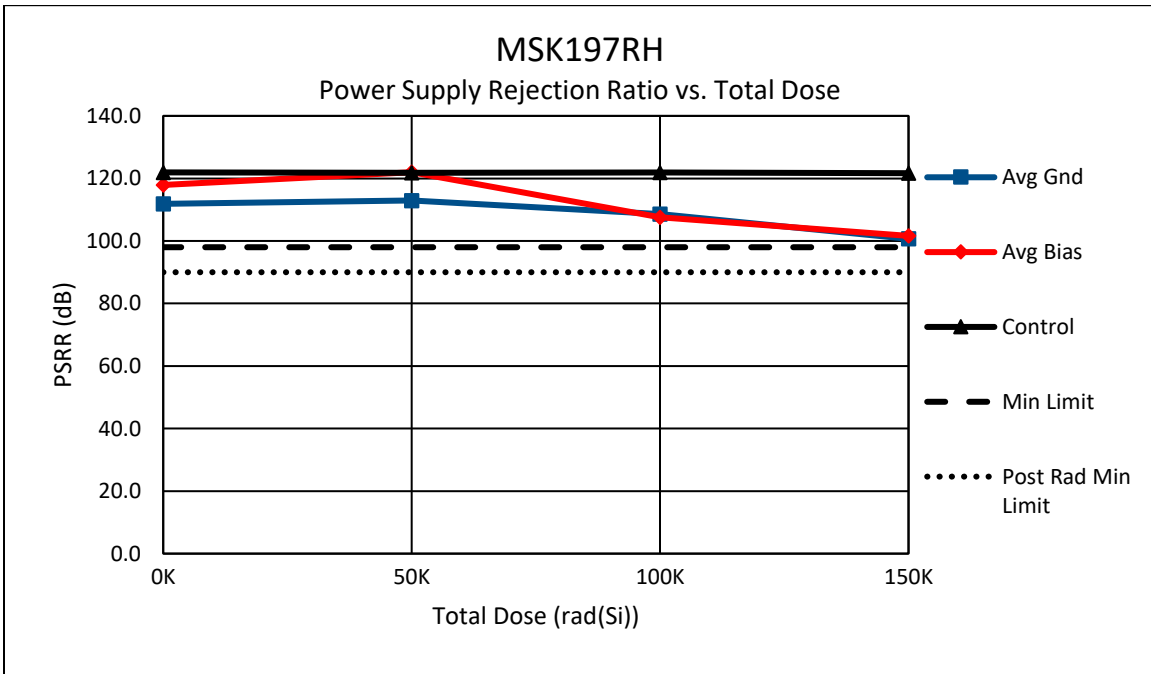
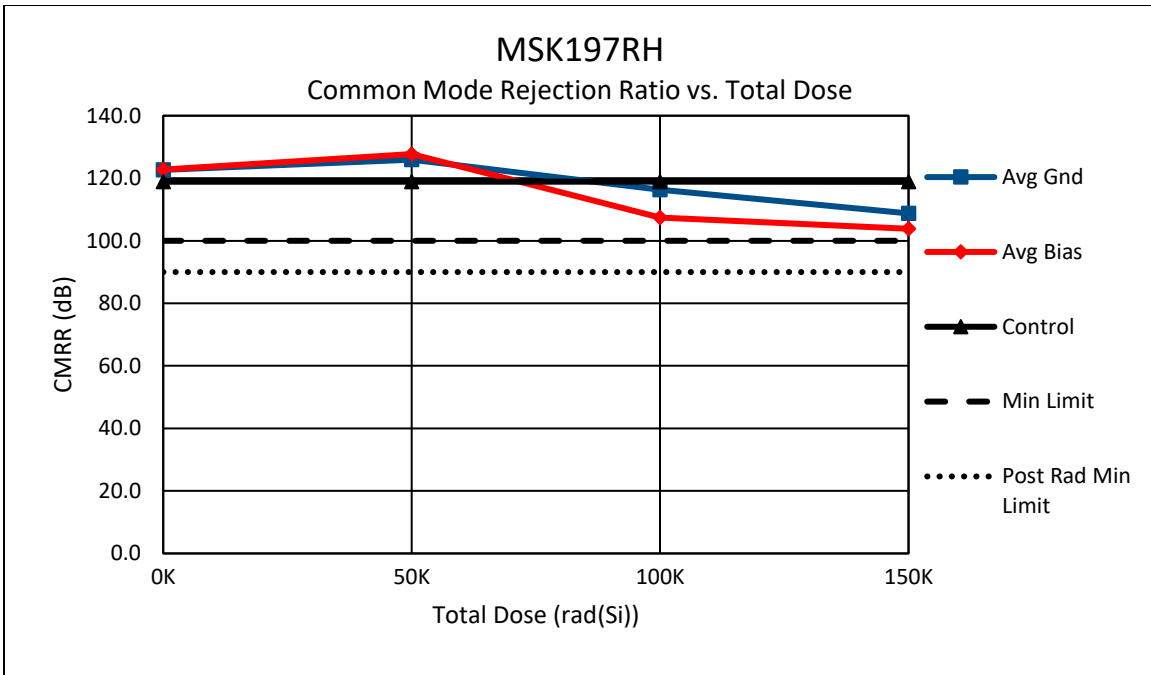
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Table 1

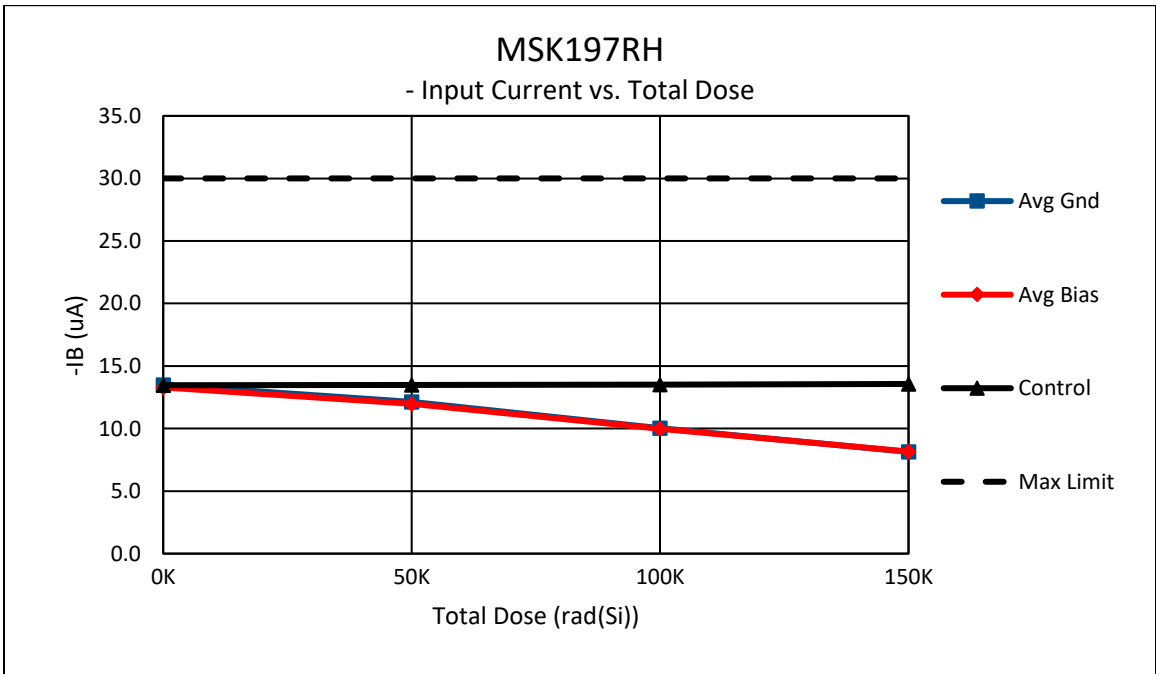
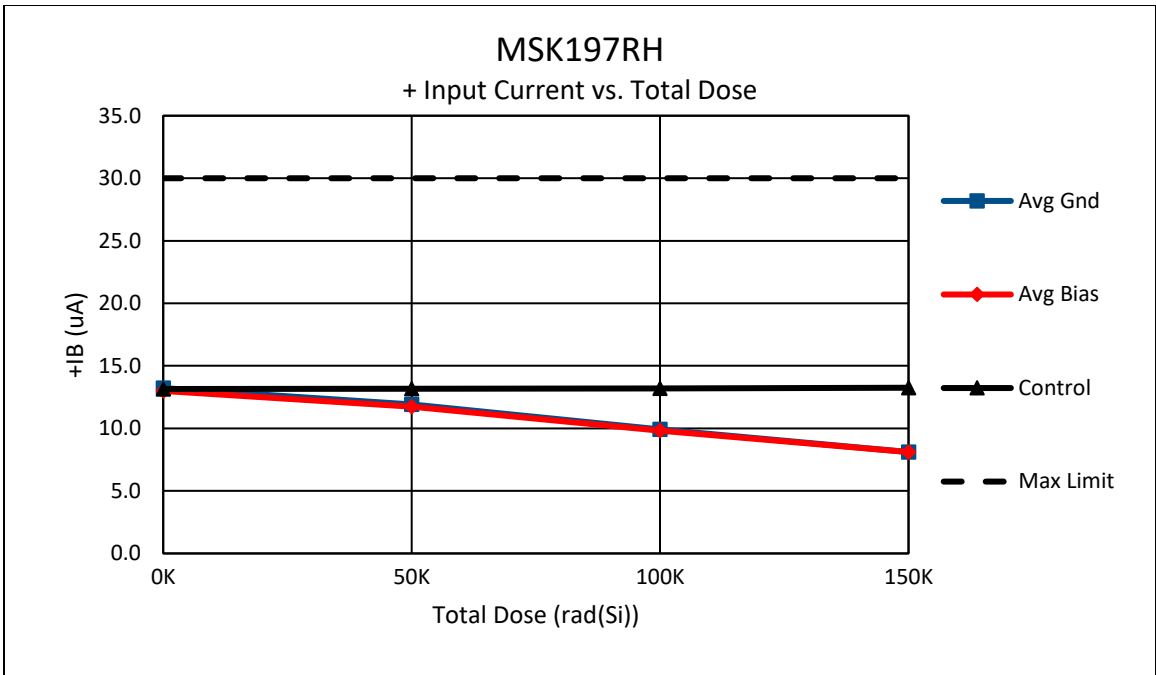
**Dose Time, Incremental Dose and Total Cumulative Dose**

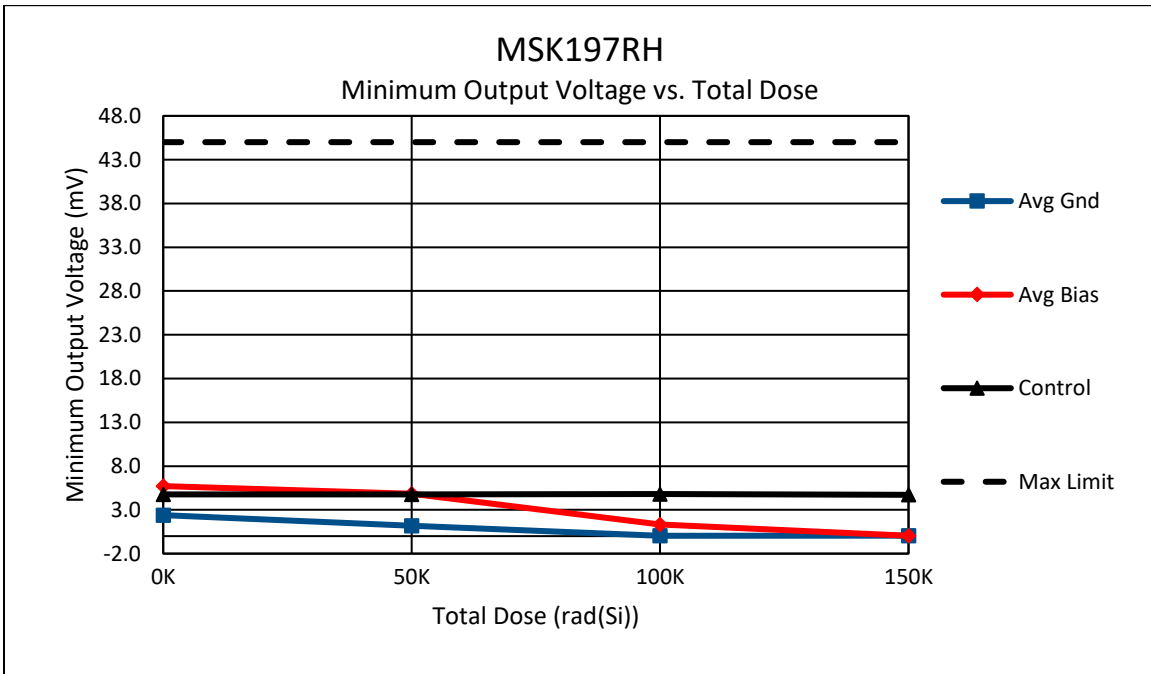
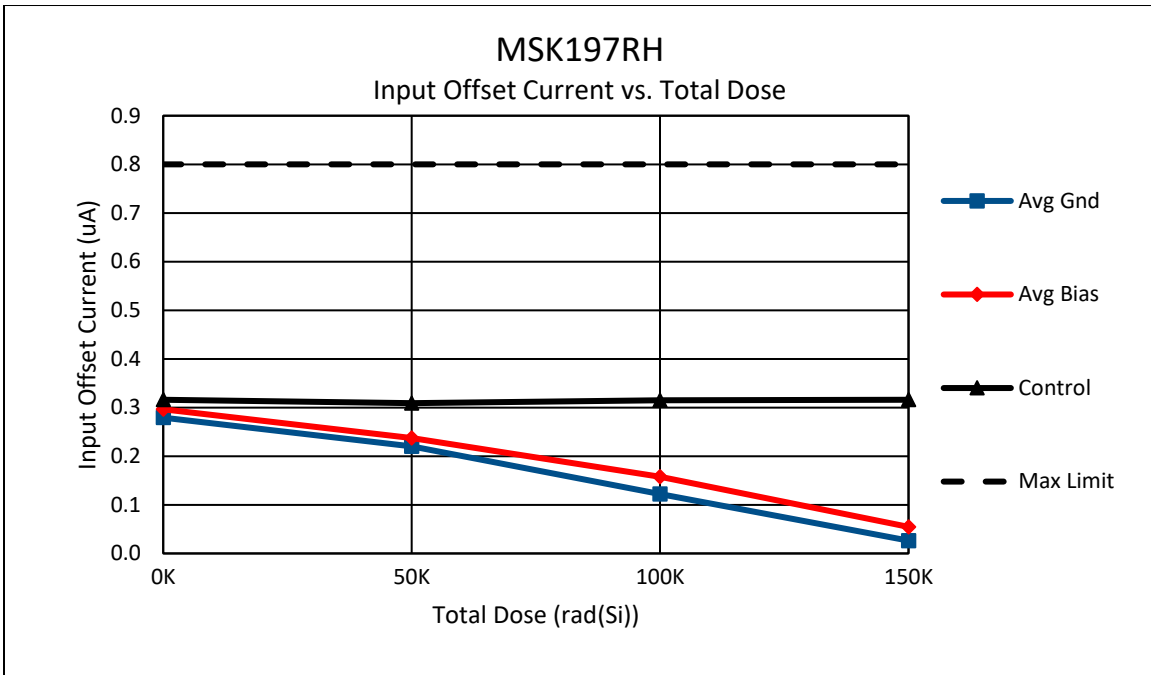


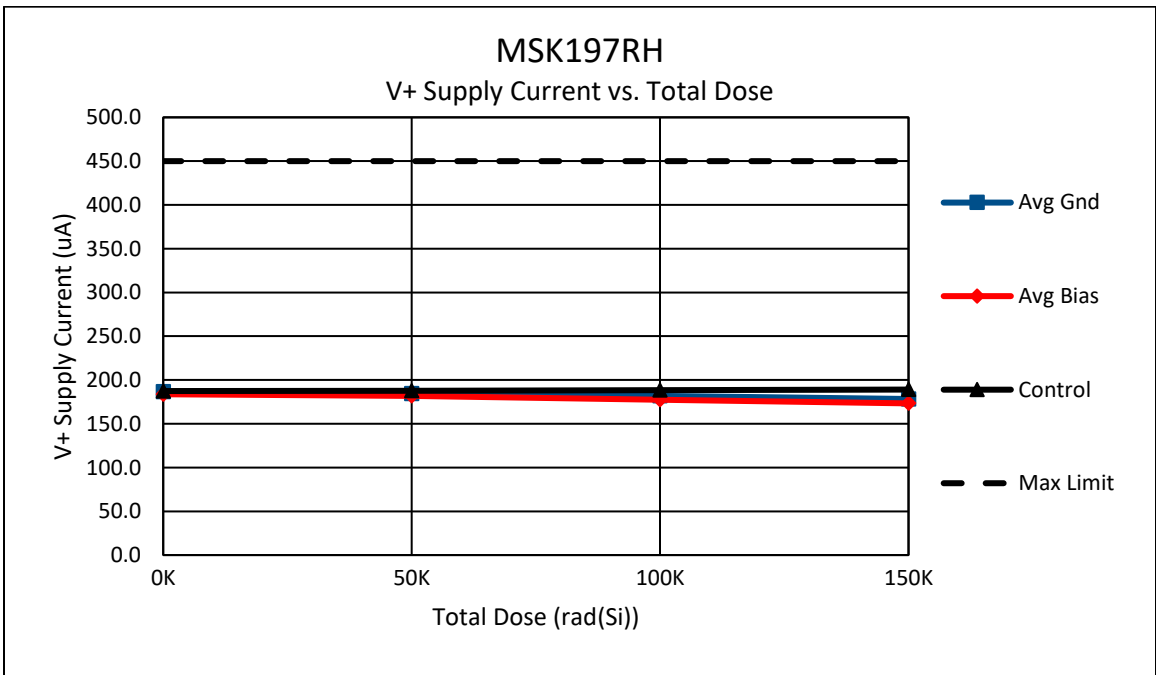
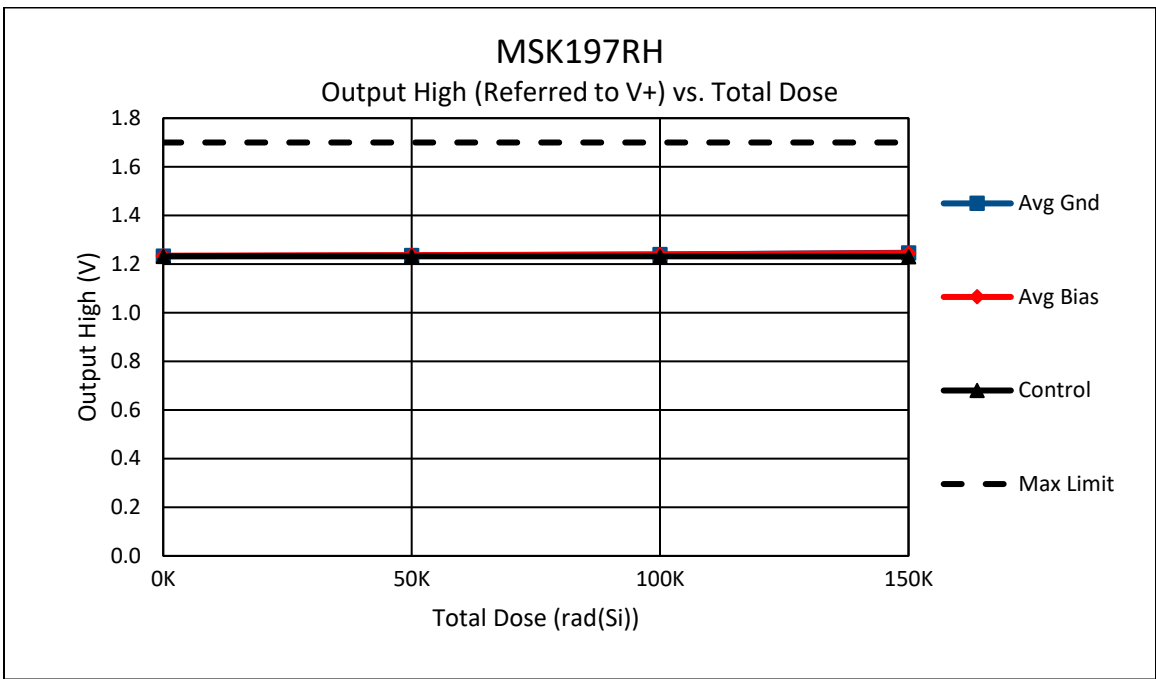












## **Neutron and Total Ionizing Dose Radiation Test Report**

**MSK196RH,  
MSK197RH,  
(MSK496RH)**

**RAD Hard (QUAD) Precision Rail To Rail Current Sense Amplifier**

May 11, 2012 (TID, First Test, WAFER LOT: WD005335.3 WF#5); Updated February 12, 2013  
March 26, 2013 (Neutron Irradiation, WAFER LOT: WD005335.3 WF#5)  
Revised May 23, 2017

B. Horton  
R. Wakeman

Anaren, Inc. – MSK Products

## **I. Introduction:**

The Neutron Irradiation test for the MSK196RH was performed to determine the change in device performance as a function of neutron fluence. The testing was performed to  $5.38 \times 10^{11}$  n/cm<sup>2</sup> total integral fluence. The test does not classify maximum radiation tolerance of the device, but simply offers designers insight to the critical parameter-shifts up to the indicated fluence levels. The MSK196RH, MSK 197RH and the MSK496RH use the same active components. The data herein is from direct measurement of the MSK196RH response to neutron irradiation, but is indicative of the response of all device types.

MIL-STD-883 Method 1017.9 was used as the basis in the development and implementation of the Neutron Irradiation test plan for the MSK196RH, MSK197RH and MSK496RH.

## **II. Radiation Source:**

Neutron Irradiation was performed at the University of Massachusetts, Lowell, using the Reactor Facility-FNI. The neutron flux was determined by dosimetry system S/P-32, method ASTM E-265, to be  $4.05 \times 10^8$  n/cm<sup>2</sup>-S (1 MeV equivalent) for each irradiation step.

## **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 burn-in per MIL-STD-883 Method 1015 and were fully screened IAW MIL-PRF-38534 Class K or MIL-PRF-38535 Class V. For test platform verification, one control device was tested at 25°C. Five devices were then tested at 25°C, prior to irradiation, and were found to be within acceptable test limits.

During irradiation, devices leads were shorted together using antistatic foam and then devices were placed into an anti-static bag. Devices were then vertically aligned with the radiation source.

After each irradiation step, the devices were transported to the MSK automatic electrical test platform. Testing was performed in accordance with the MSK196RH data sheet. Electrical testing was performed on the irradiated devices, as well as the control device, at each fluence level. Electrical tests were completed within twenty four hours of irradiation.

## **IV. Data:**

All performance curves are averaged from the test results of the irradiated devices. If required, full test data can be obtained by contacting Anaren, Inc. – MSK Products.

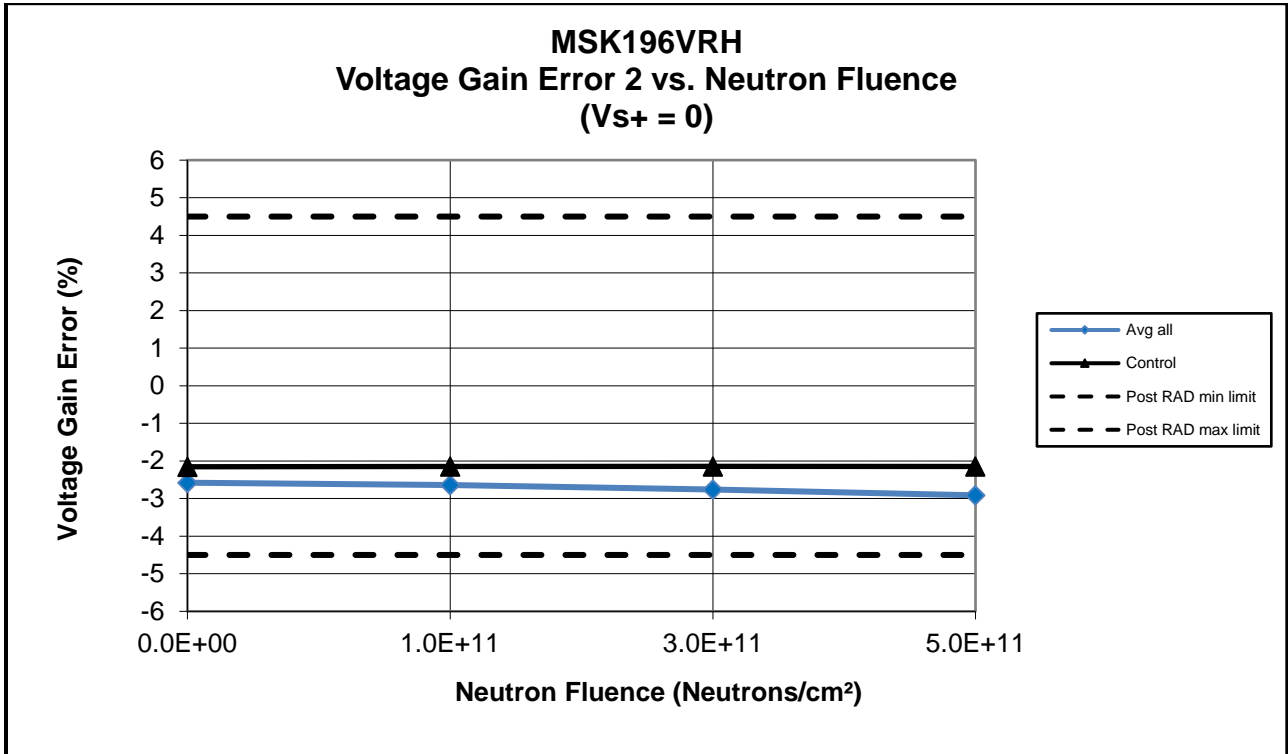
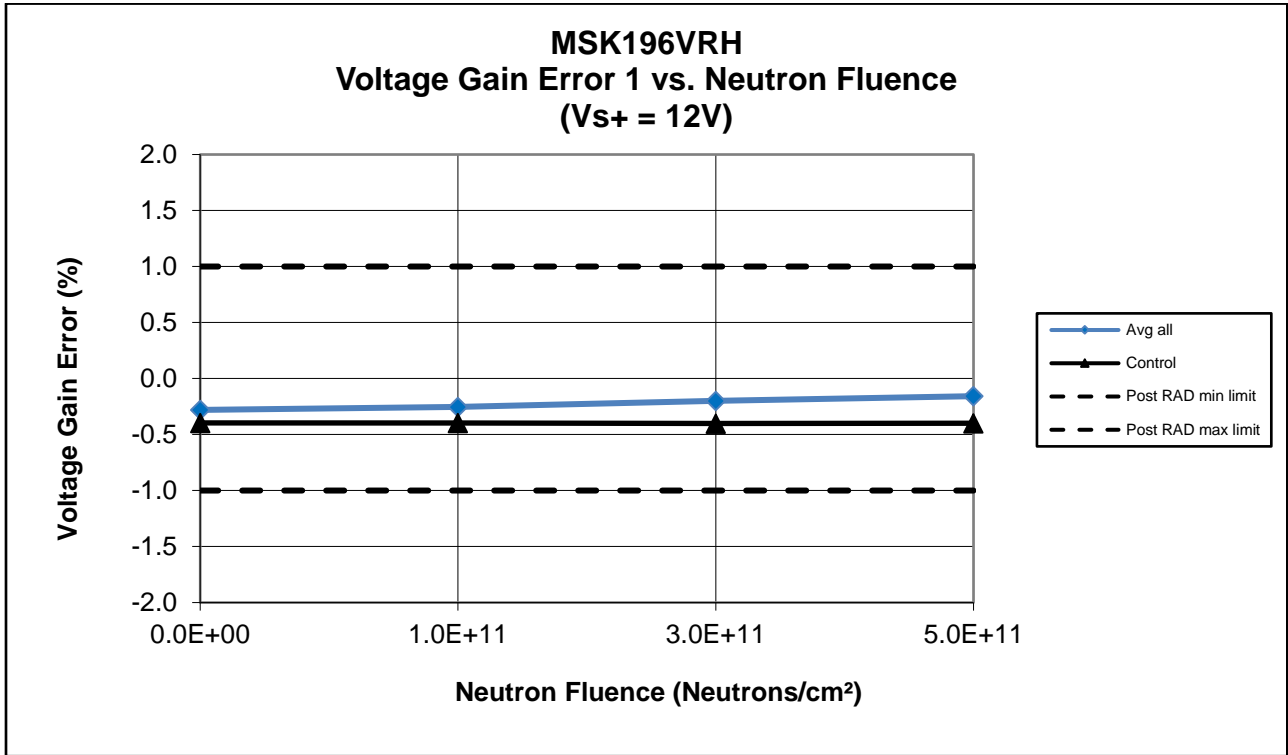
## **V. Summary:**

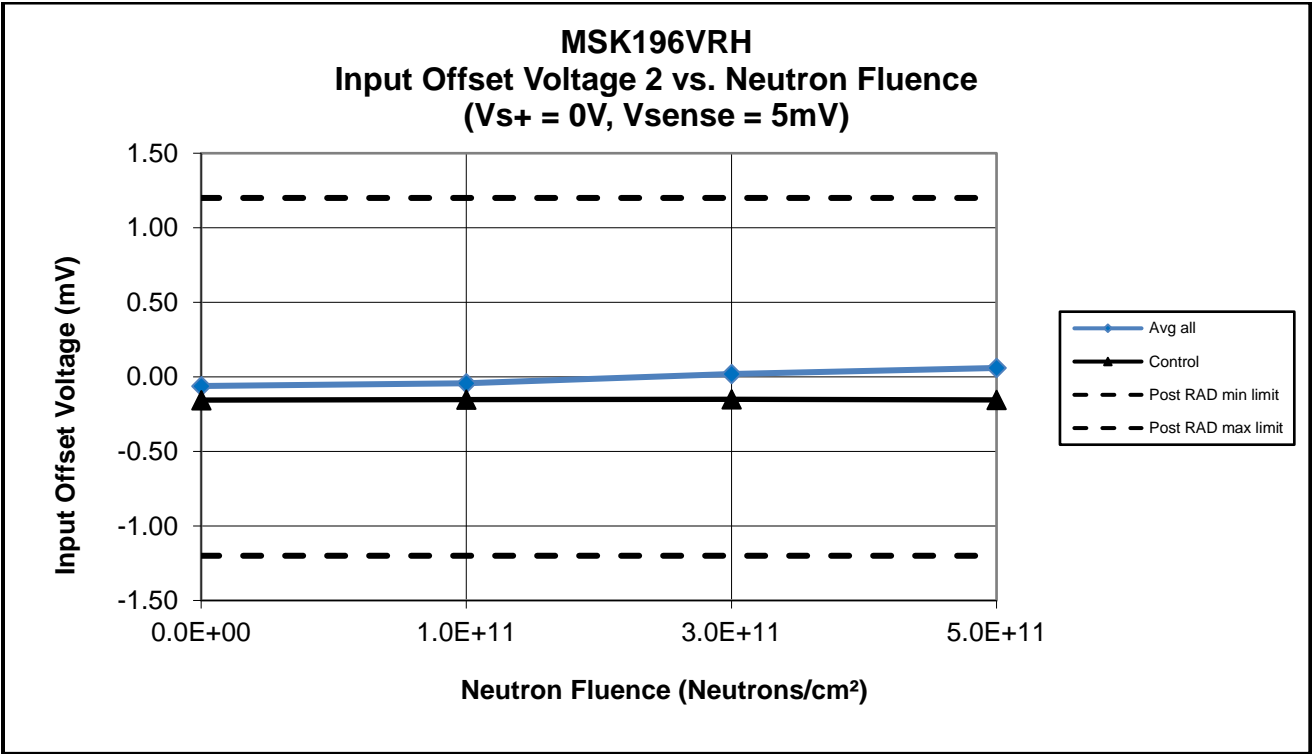
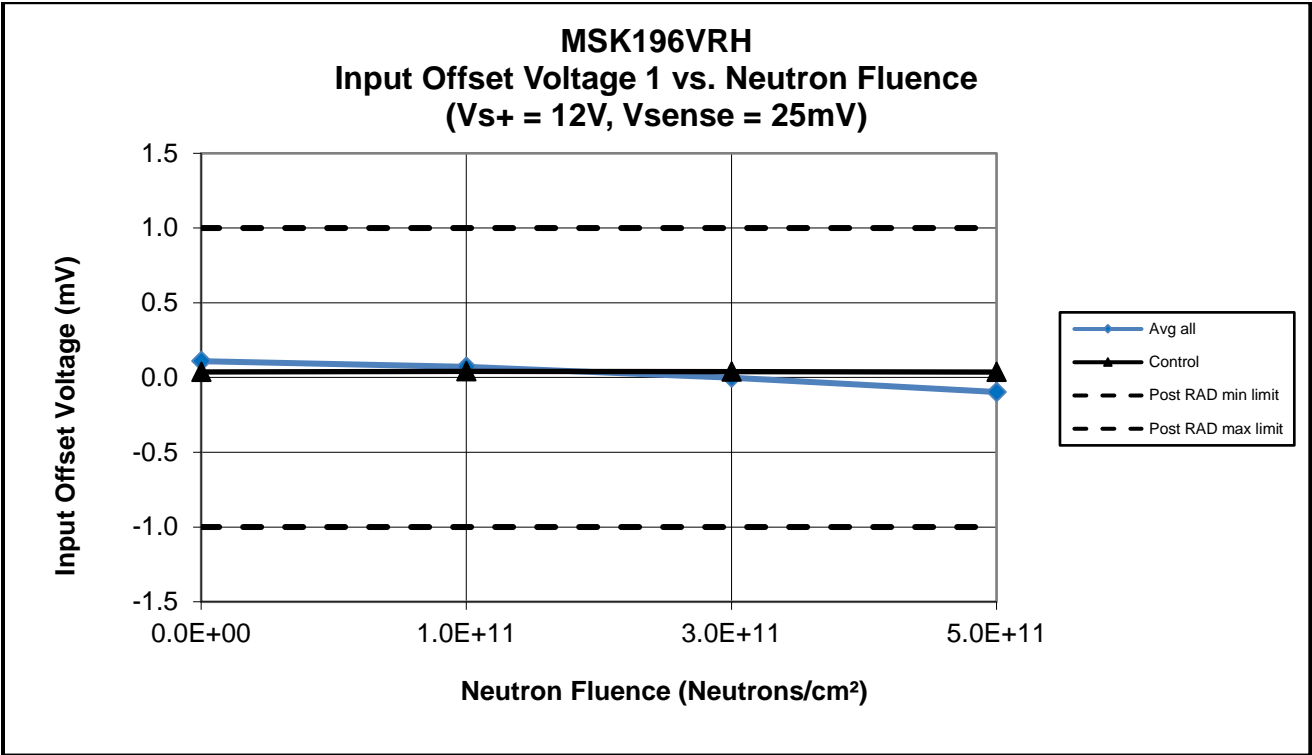
Based on data recorded during neutron irradiation testing and statistical analysis, the MSK196RH, MSK197RH and MSK496RH exhibit low susceptibility to neutron displacement damage. All devices performed well within data sheet specifications throughout all test intervals.

Table 1.

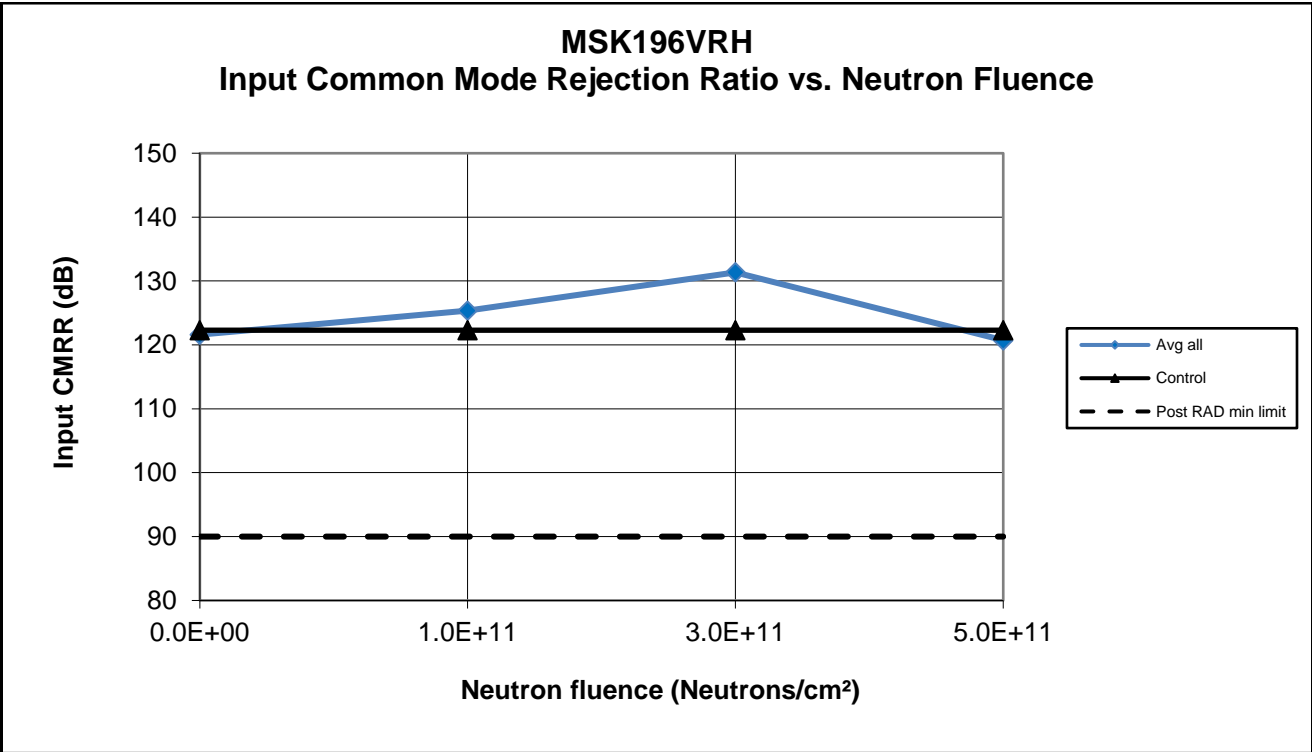
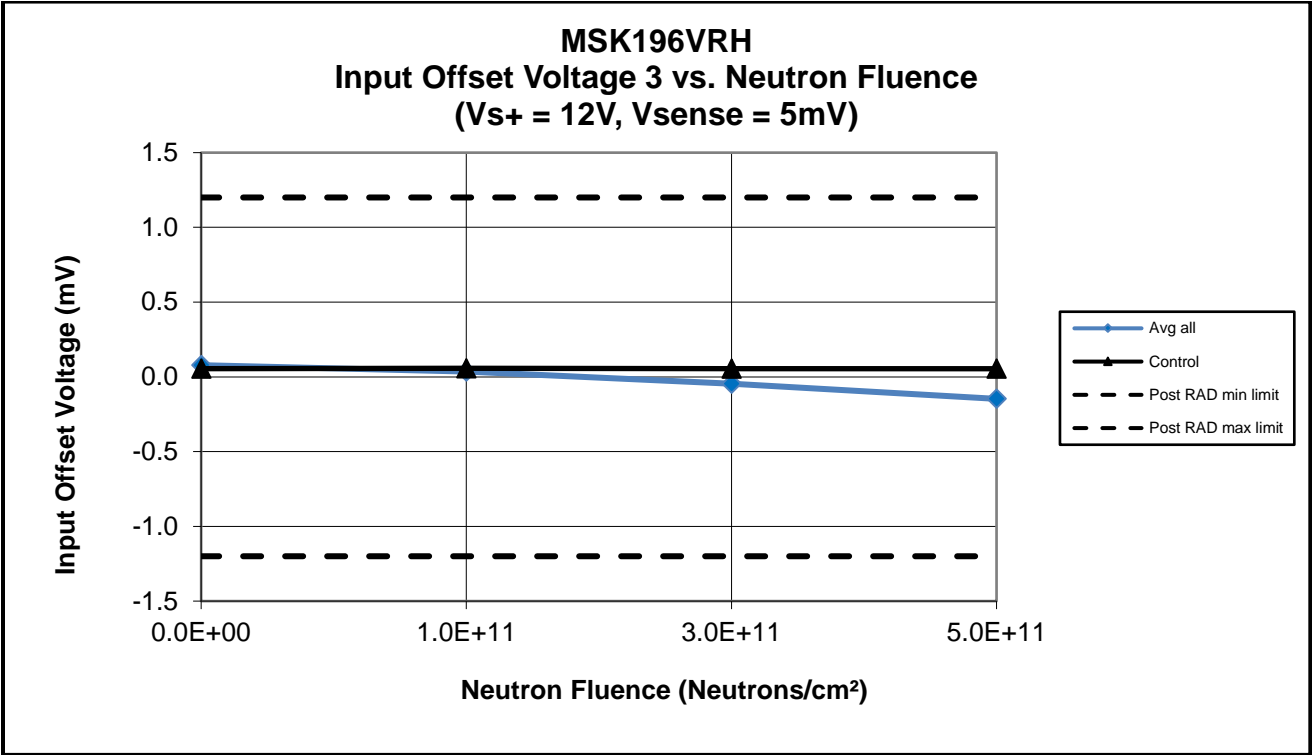
MSK196RH Neutron Irradiation						
Reactor Facility – Fast Neutron Irradiation (FNI) Dosimetry System: S/P-32 (ASTM E-265)						
Exposure Date: 3/26/13						
Irradiation	Reactor Power (kW)	Gamma Dose Rad (Si)	Flux (n/cm <sup>2</sup> -S)	Time(s)	Fluence (n/cm <sup>2</sup> )	Total Fluence (n/cm <sup>2</sup> )
Step 1	5	14	4.05E8	247	1.14E11	1.14E11
Step 2	5	28	4.05E8	494	2.14E11	3.28E11
Step 3	5	28	4.05E8	494	2.10E11	5.38E11

**Gamma Dose, Neutron Flux and Total Fluence**

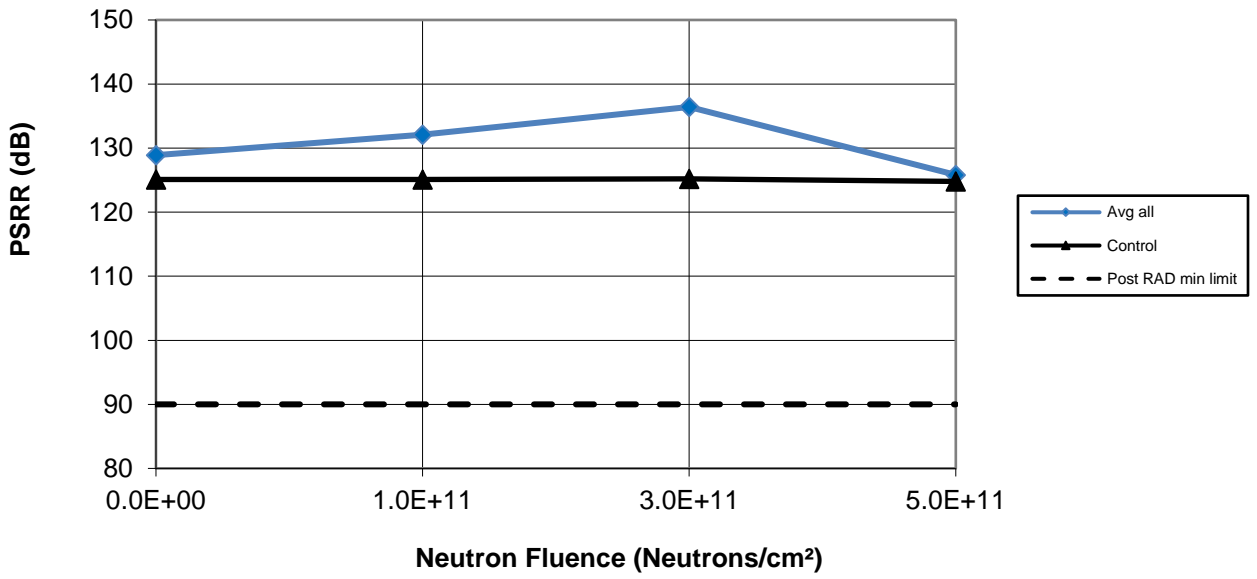




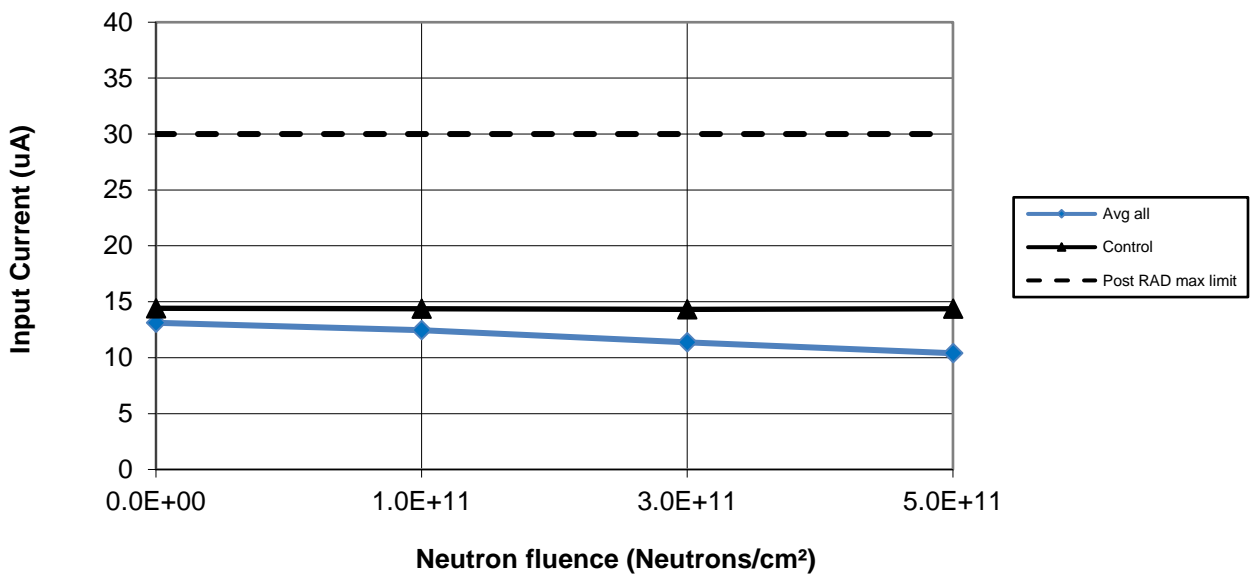


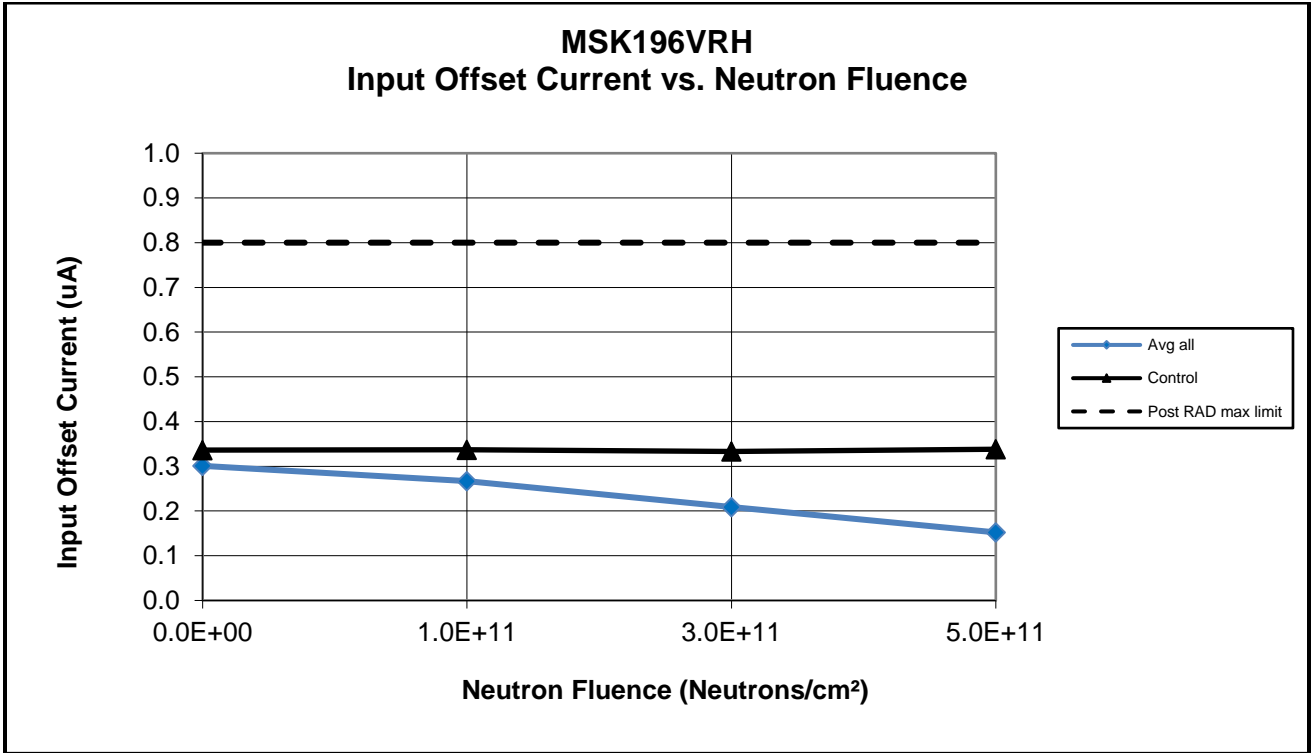
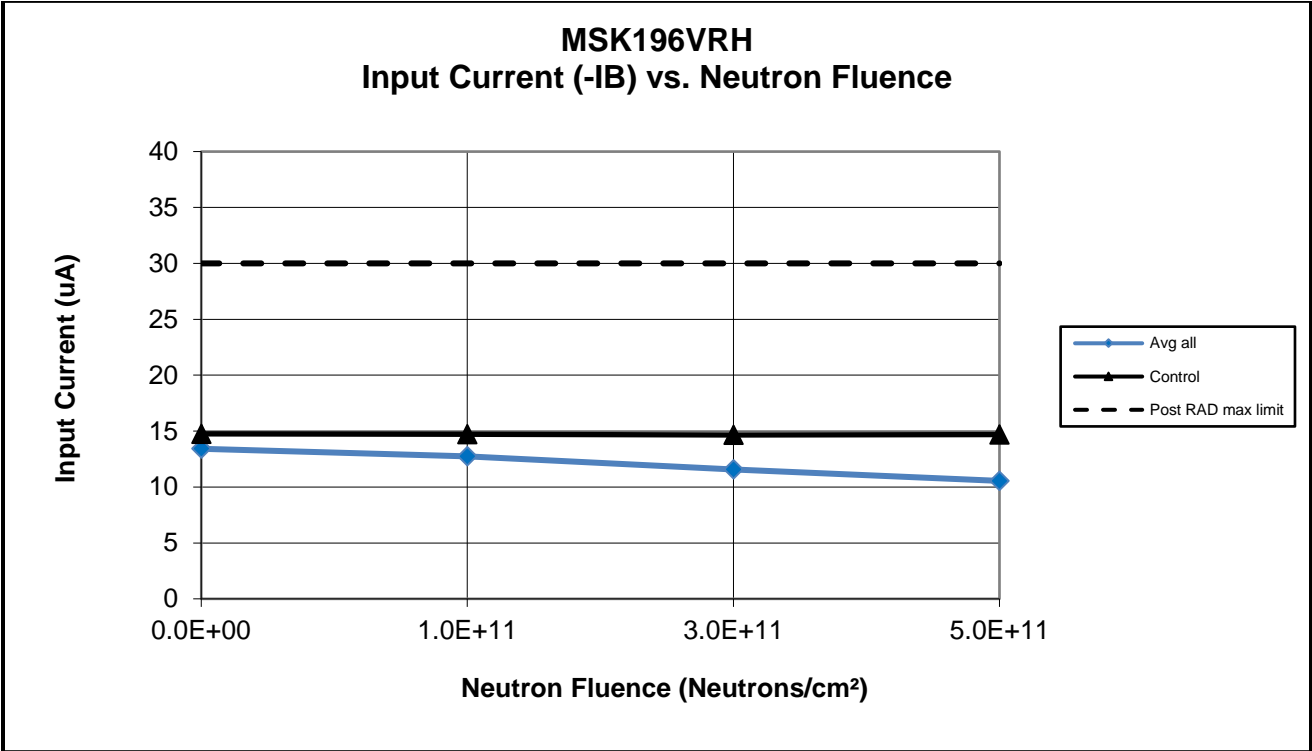


**MSK196VRH**  
**Power Supply Rejection Ratio vs. Neutron Fluence**

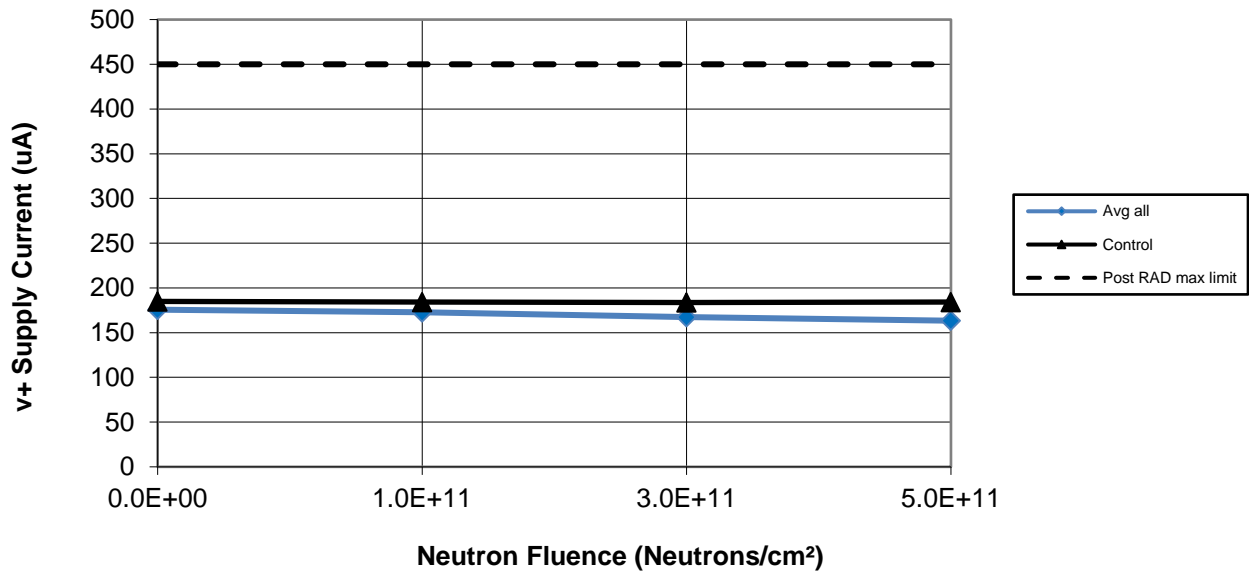


**MSK196VRH**  
**Input Current (+IB) vs. Neutron Fluence**

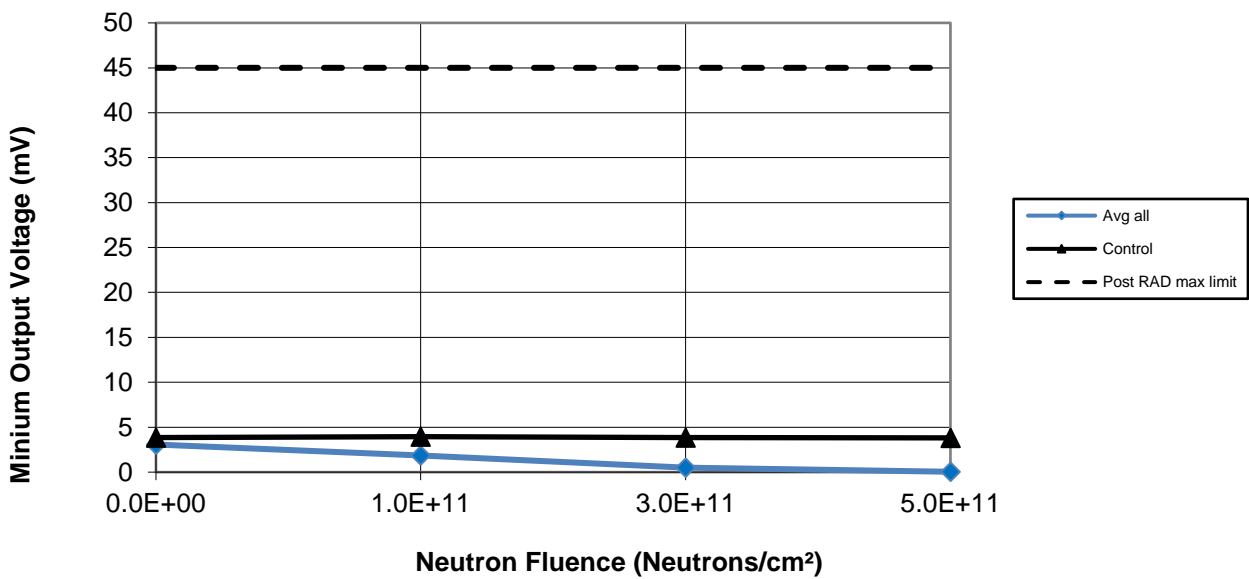




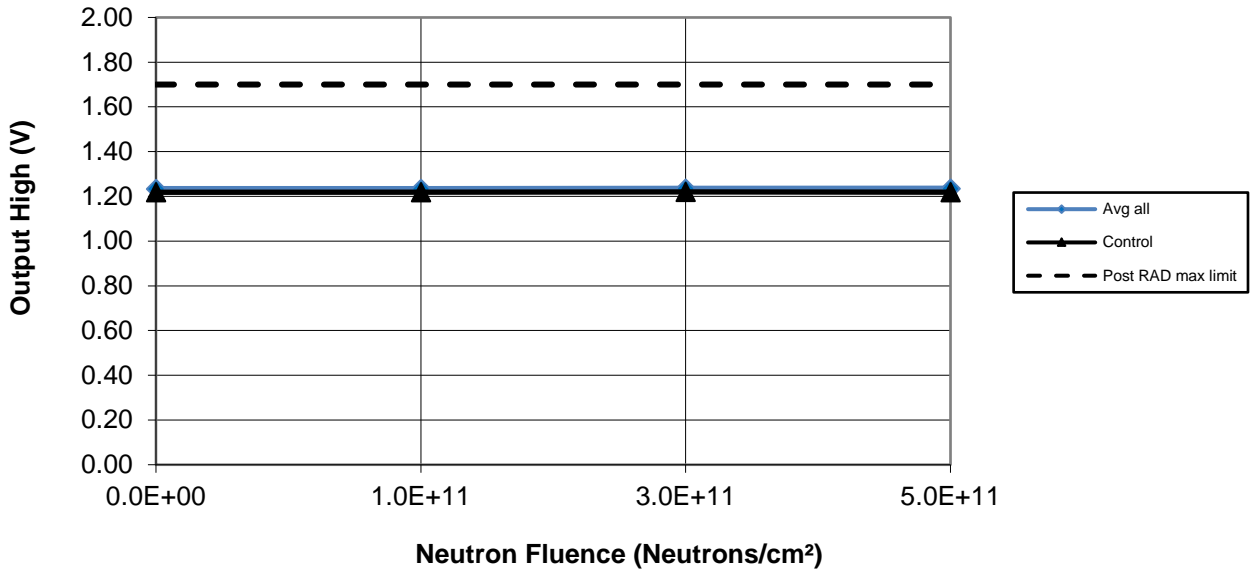
**MSK196VRH**  
**V+ Supply Current vs. Neutron Fluence**



**MSK196VRH**  
**Minimum Output Voltage vs. Neutron Fluence**



**MSK196VRH**  
**Output High (referred to V+) vs. Neutron Fluence**



## **Total Dose Radiation Test Report**

**MSK196RH,  
MSK197RH  
(MSK496RH)**

**RAD Hard (QUAD) Precision Rail To Rail Current Sense Amplifier**

May 11, 2012 (TID, First Test, WD005335.3 WF#5)  
Updated February 12, 2013

B. Horton  
K. Conroy  
R. Wakeman

Anaren, Inc. – MSK Products

## **I. Introduction:**

The total dose radiation test plan for the MSK 196RH was developed to qualify the devices as RAD Hard 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 device, but simply offers designers insight to the critical parameter-shifts up to the specified total dose level. The MSK196RH, MSK197RH and MSK496RH use the same active components. The data in this report is from direct measurement of the MSK196RH response to irradiation but it is indicative of the response of all devices and is applicable to all.

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 196RH, MSK197RH and MSK 496RH.

## **II. Radiation Source:**

Total dose was performed at the University of Massachusetts, Lowell, using a cobalt 60 radiation source. The dose rate was determined to be 109 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 burn-in per MIL-STD-883 Method 1015 and were fully screened IAW MIL-PRF-38534 Class K or MIL-PRF-38535 Class V. For test platform verification, one control device was tested at 25°C. Ten 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. Five devices were kept under bias during irradiation. An operating voltage of +30 Volts was used for the bias condition. Five devices had all leads grounded during irradiation for the unbiased condition.

After each irradiation, the device leads were shorted together and the devices were transported to the MSK automatic electrical test platform. Testing was performed in accordance with the 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. Devices were subjected to subsequent radiation doses within two hours of removal from the radiation field.

## **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:**

Based on the test data recorded during radiation testing and statistical analysis, the MSK196RH, MSK197RH and MSK496RH qualify as a 100 KRad(Si) radiation hardened devices. Voltage Gain Error 2 ( $V_s \neq 0V$ ), Input Offset voltage, PSRR and CMRR exhibited the most significant shift due to irradiation. All other parameters stayed within pre-irradiation specification up to 150KRad(Si).

MSK 196 VRH Biased/Unbiased Dose Rate Schedule
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Dosimetry Equipment
Bruker Biospin # 0162

Irradiation Date
5/11/12

Exposure Length (min:sec)	Incremental Dose rads(Si)	Cumulative Dose rads(Si)
08:00	51,840	51,480
08:00	51,840	103,680
08:00	51,840	155,520

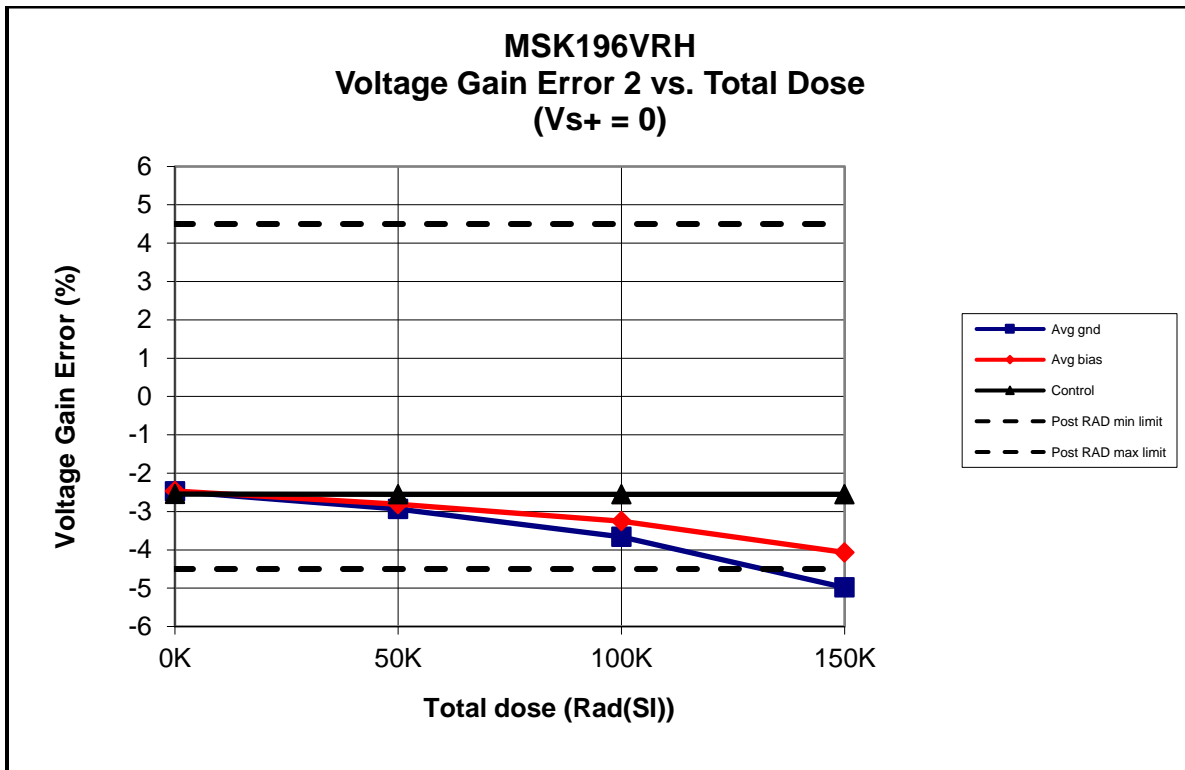
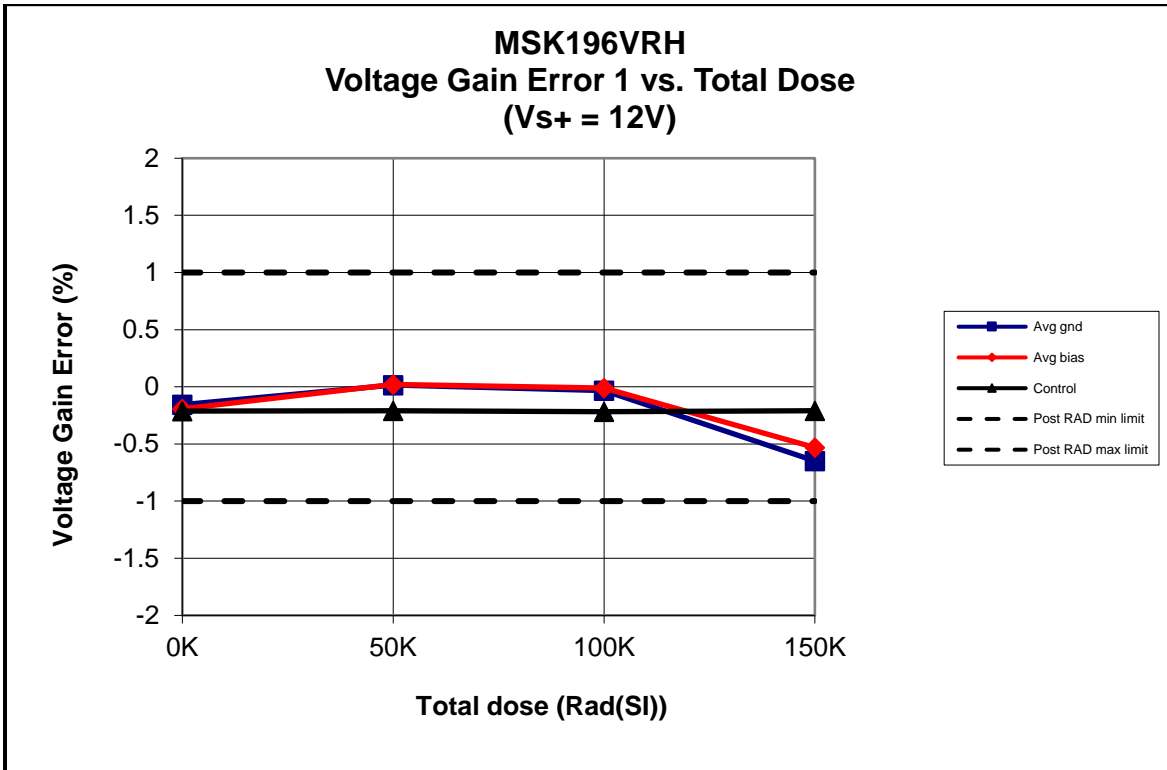
Biased S/N – 0014, 0015, 0016, 0017, 0018
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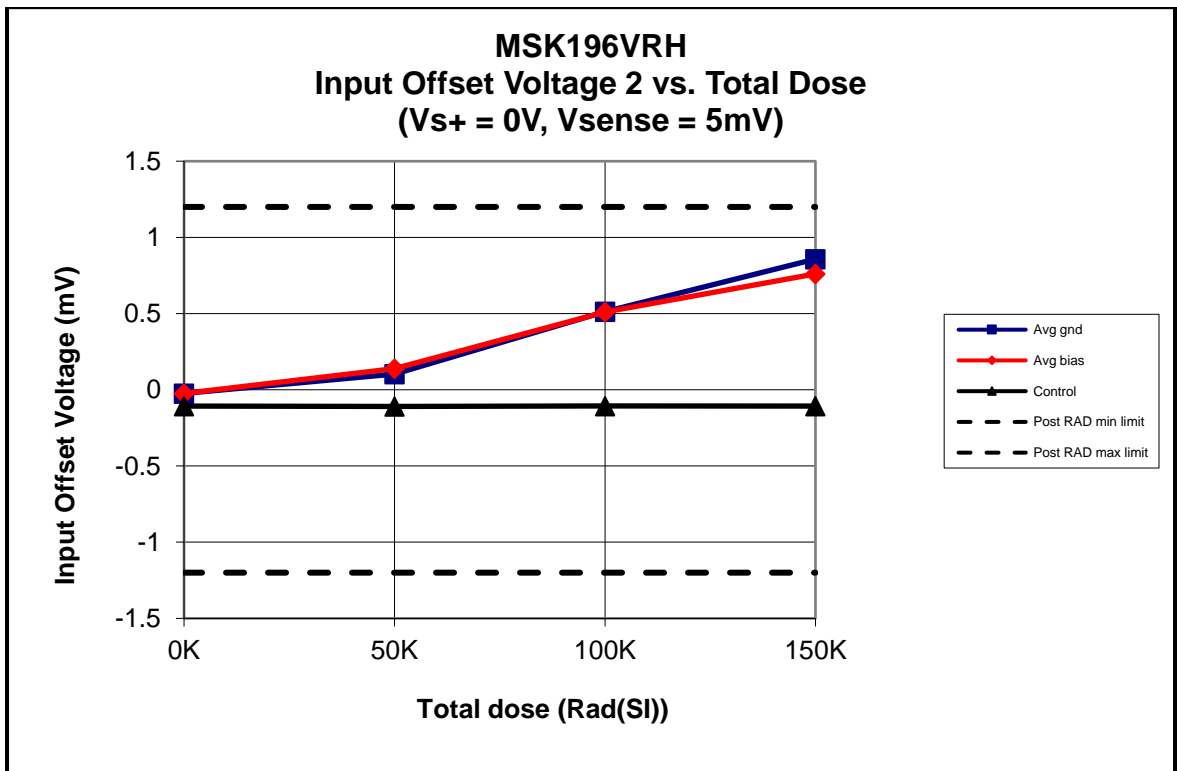
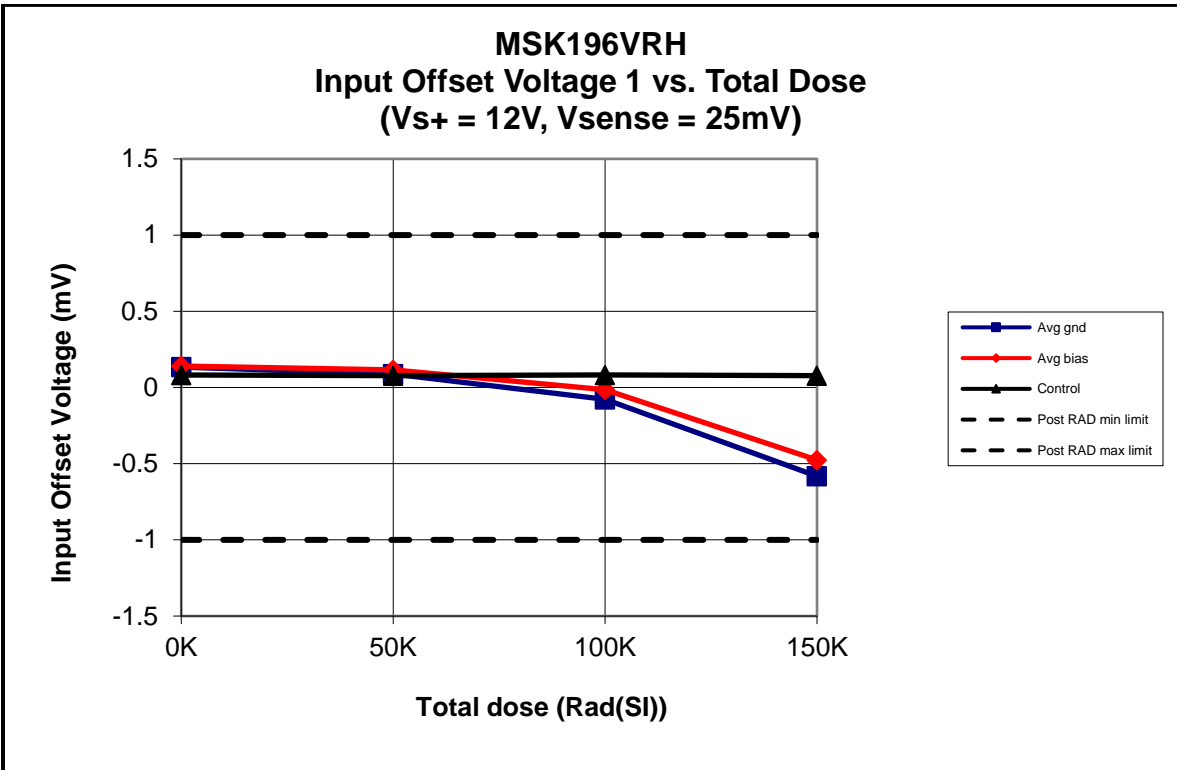
Unbiased S/N – 0019, 0020, 0021, 0023, 0024
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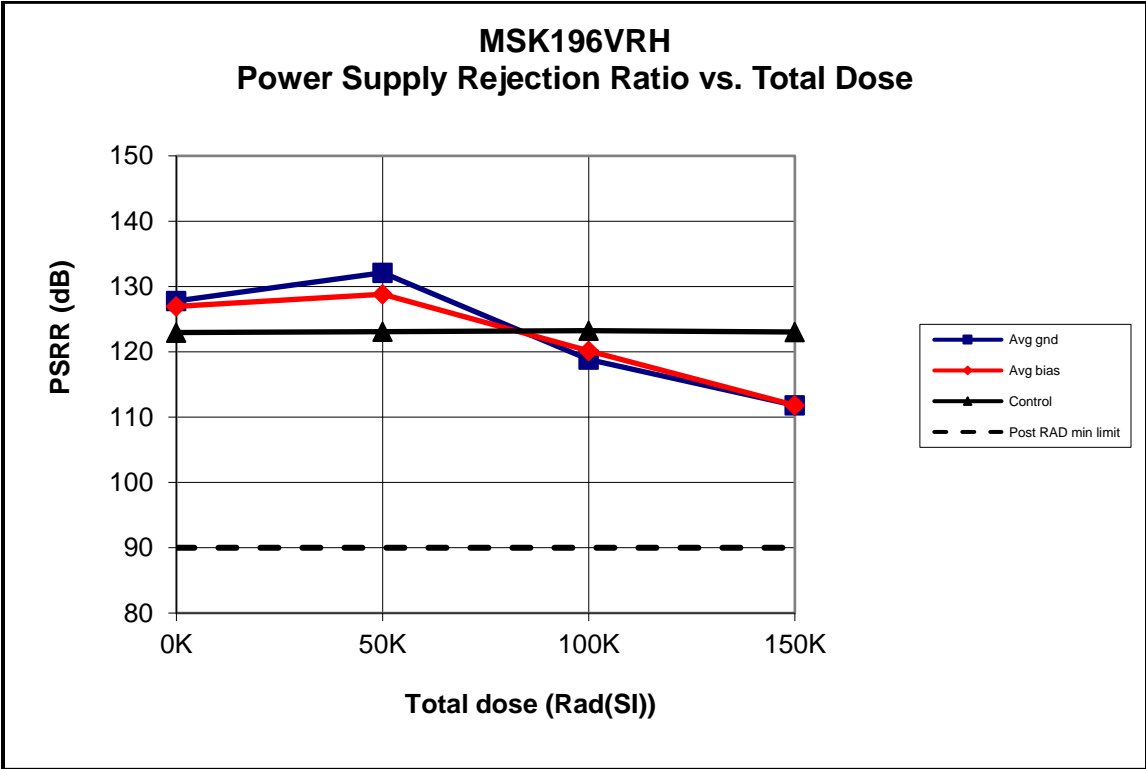
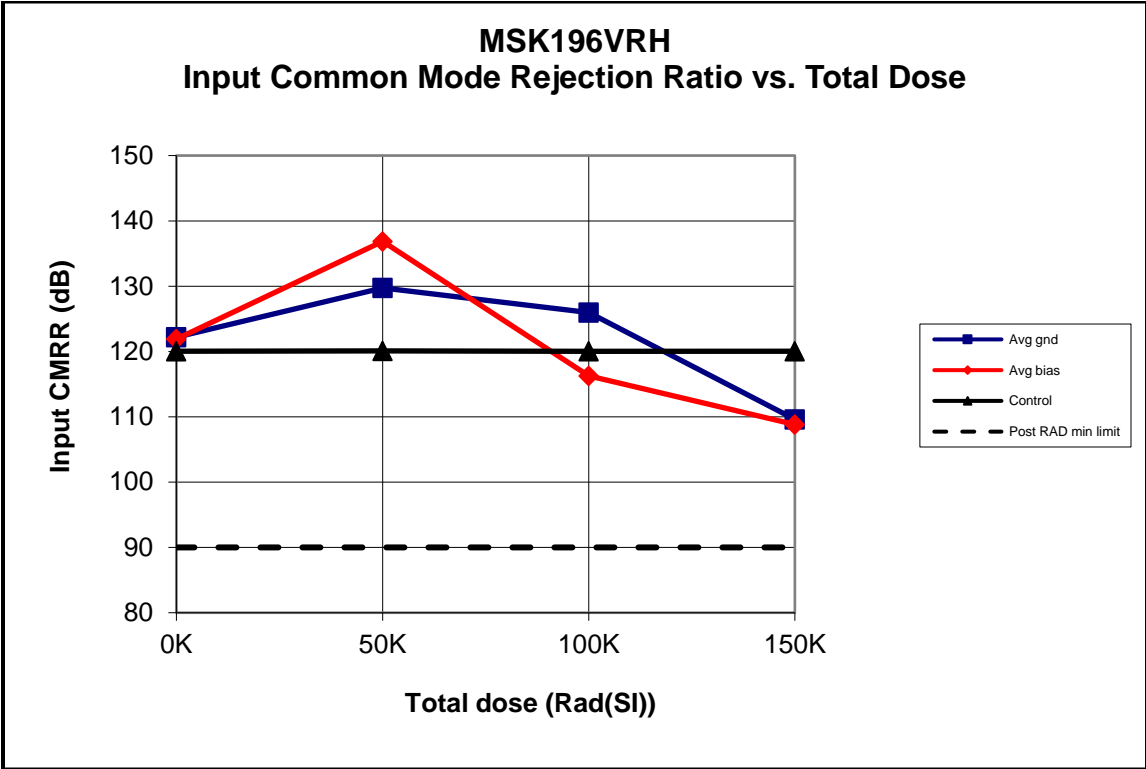
Table 1

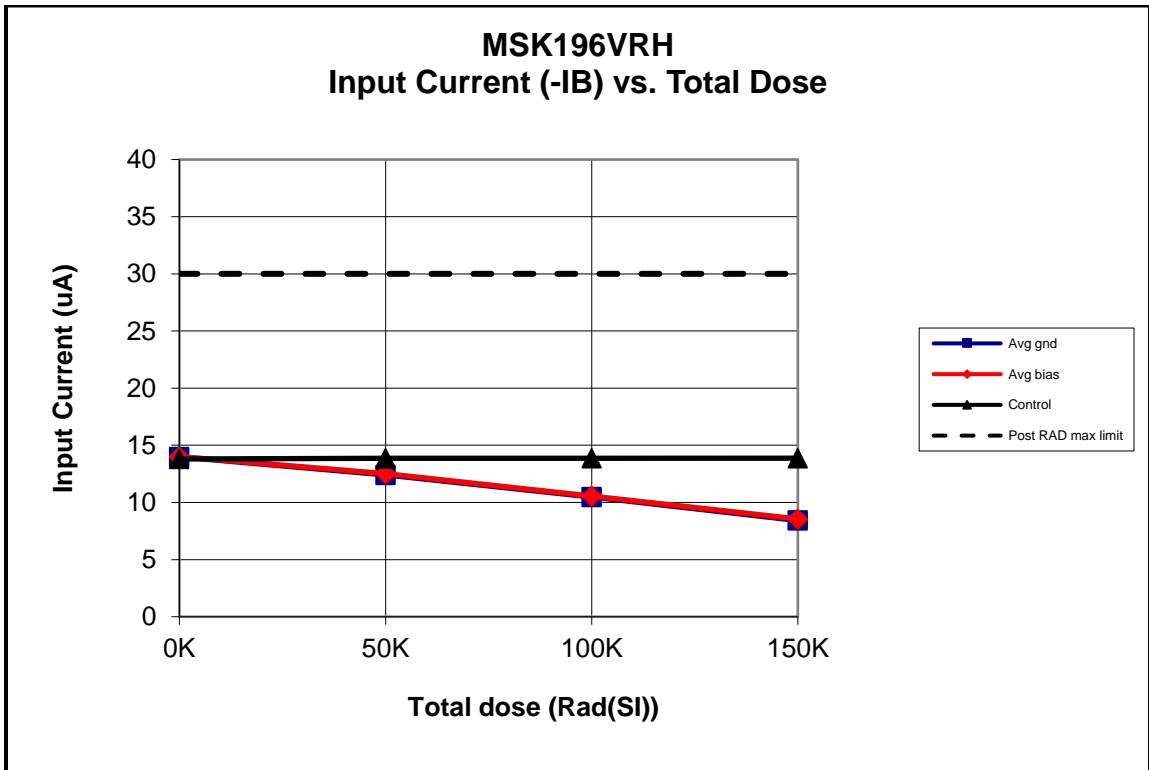
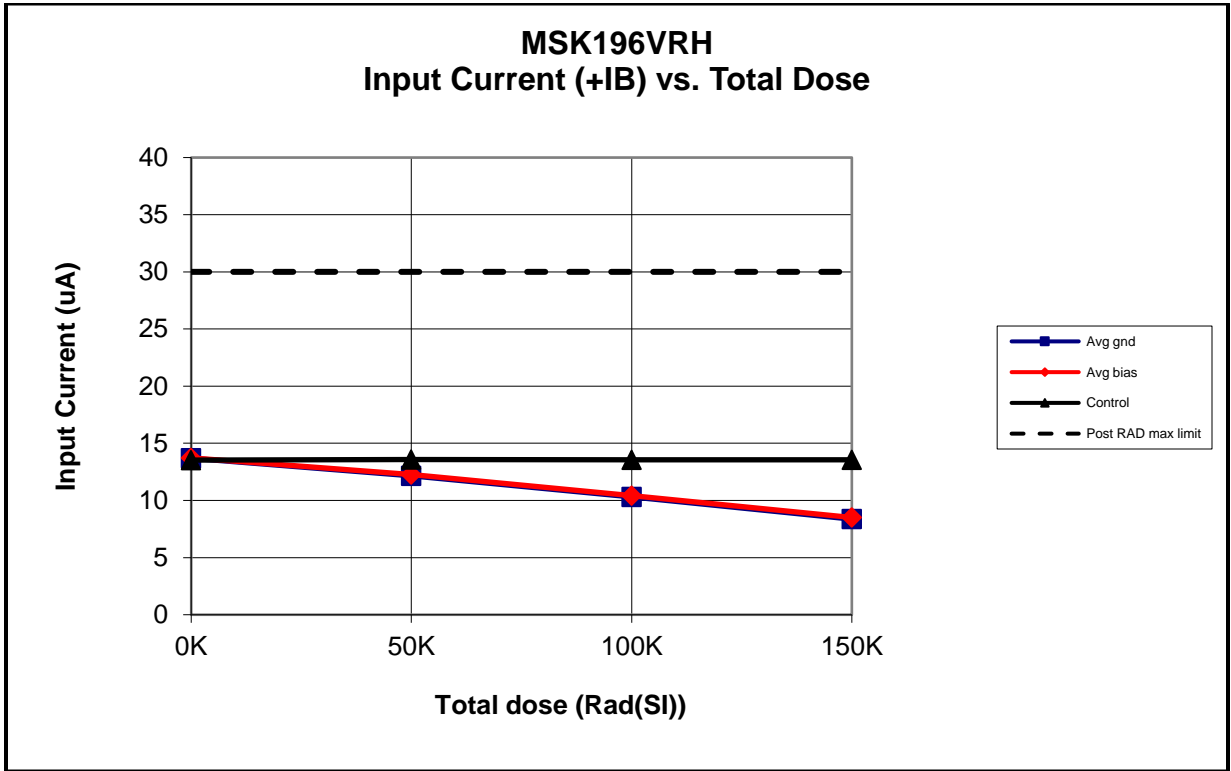
**Dose Time, Incremental Dose and Total Cumulative Dose**



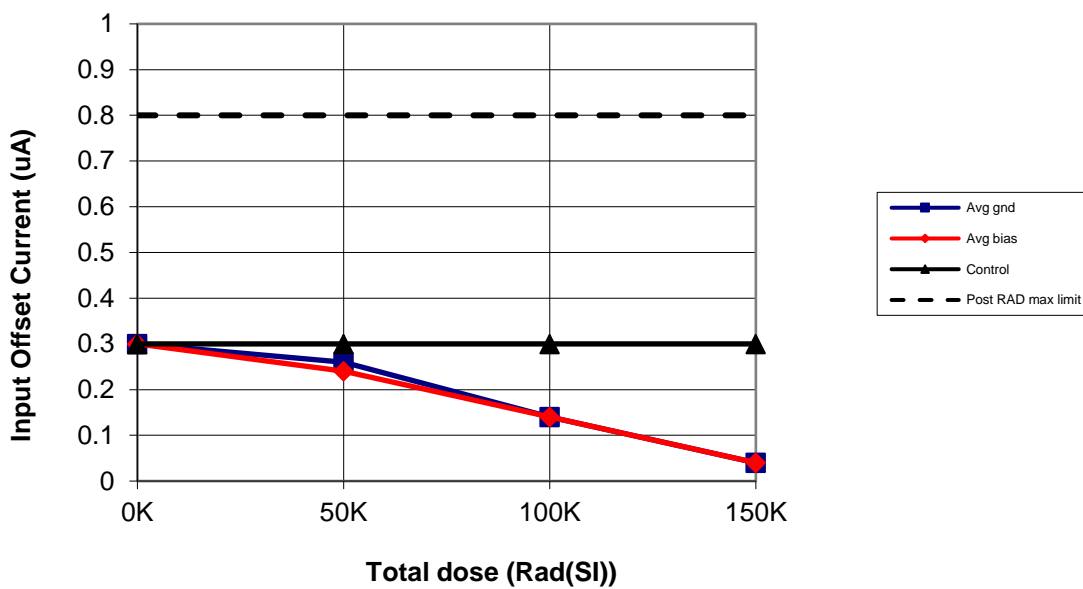








**MSK196VRH**  
**Input Offset Current vs. Total Dose**



**MSK196VRH**  
**V+ Supply Current vs. Total Dose**

