Total-Dose Radiation Effects Characterization Engineering Evaluation Report for LM6161J/883

Final

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I. INTRODUCTION

This report summarizes the results of total-dose irradiation of LM6161J/883 device. These results will provide circuit designers information regarding reliability of the device and the trends in performance after accumulating a large radiation dose. Based on this information, designers will be able to incorporate appropriate safeguards into their circuits.

These characterization tests did not perform attribute testing, i.e., use a pass/fail criteria. Instead, they simply show trends in the critical parameters as a function of total-dose. Room temperature acceptance limits are shown on all graphs and tables only for the purpose of comparison. All devices were exposed to a total dose of 200k Rads (Si)[1] and data was collected whether or not parts were in spec.

MIL-STD-883D method 1019.4 was used for the most part as a guideline for these tests. Parts were tested only with dose rate condition A, which tests for total-dose effects. Condition B, which tests for prolonged low dose effects was not used as the Gammacell 220 does not have the capability to produce radiation at low dose rate. Once a baseline is established with the help of this characterization, individual wafer lots can be qualified using the appropriate dose rate conditions.

The LM6161 is a high speed low power amplifier with 300V/ms slew rate, 500 MHz unity gain bandwidth, and 5mA supply current. It is ideal for low power high performance applications. It is fabricated with National's VIP (Vertically Integrated PNP) technology which improves PNP transistor performance. Since PNP transistors are more susceptable to radiation effects, any improvement in their performance will improve overall radiation tolerance of the device.

II. SUMMARY

All 39 samples were exposed to a total-dose of 200k Rads and all critical parameters were measured at various steps during the irradiation. These parameters were found to be sensitive to radiation. Parameters not mentioned here remained stable or changed marginally.

1. Input offset voltage remained within the room temperature limits until 30k Rads. All parts met hot/cold temperature limits at 200k Rads.

2. Supply current showed minor degradation. All parts were in room temperature limits at 200k Rads

3. Input bias current data appears to be skewed from the beginning. At the pre-rad level all samples were found to be very close to the upper room temperature limit. At 3k Rads some parts were falling out of the upper room temperature limit even though no significant change on average has taken place compared to the pre-rad level. Actual deterioration begins at roughly 10k Rads. At 50k Rads, some parts are out of the hot and cold temperature limit.

4. Input offset current remained stable up to 50k Rads. At 100k Rads, some parts are out of room temperature upper limit. All devices are inside hot/cold temperature limits at 200k Rad.

5. CMRR decreases roughly 10dB after 200k Rads exposure and remains above the room temperature limit. PSRR drops below the room temperature limit at 100k Rads but remains inside the hot and cold limit up to 200k Rads.

6. Total gain falls out of room temperature limit at 1k Rads (Si). It falls below the hot and cold temperature limit at 100k Rads.

III. APPLICABLE DOCUMENTS

1. MIL-STD-883D, method 1019.4.

2. "Reliability Processing Instructions for Gammacell 220", NSC internal document, revision X.

[1] For the purpose of this report, assume 1 Rad = 1 Rad (Si)

3. QR6161ENG test program- Teradyne A360 test program which tests all parameters listed in the MDS[2] with no upper or lower limit.

IV. RADIATION SOURCE

A. Type

Atomic Energy of Canada Limited cobalt 60 irradiation unit model Gammacell 220 was used to irradiate the devices under test. The Gammacell 220 produces gamma radiation photons approximately 2.2MeV in energy.

B. Dosimetery

Advance dosimetery calculations are required by MIL-STD-883D method 1019.4. For Gammacell 220, dosimetery calculations were performed in advance at the time of last qualification. The exact values were tabulated in RPI.[3]

V. TEST SAMPLES

The original sample set consisted of a total of 15 parts chosen from 3 wafer lots, 5 parts from each lot. The parts were numbered 1 through 15. When analyzing data for these 15 parts, part #6 posed extreme difficulty in presenting the graphs. Its data laid at the extreme and caused the scales on the graphs to compress and hide the overall behavior of the other 14 parts. It was clear that trends in overall performance were not altered by the data from part #6, i.e., absence of part #6 data did not improve performance characteristics. But its presence make it more difficult to see these characteristics. Based on this reasoning, part #6 data was eliminated. 25 more parts (numbered 16 through 40) were tested. 5 parts were obtained from each of the three original wafer runs and 10 more parts from a 4th wafer run.

Samples	**Wafer Run**
1 - 5	L0015022
6	Discarded
7 - 10	AA029944X
11 - 15	AM047346X
16 - 20	SG9Y2030A019
21 - 25	AM047346X
26 - 30	SG9Y2030A019
31 - 35	AA029944X
36 - 40	L0015022

Table 1: Sample set, (total 39 samples)

Data presented in this report comes from 39 parts, 10 parts from 3 different wafer runs and 9 parts from a 4th wafer run. These parts were irradiated in two batches 16 days apart, on August 4, 1995 (parts 1 - 15, part #6 eliminated) and August 21, 1995 (parts 15 - 40) respectively. All 39 devices had passed burn-in tests.

VI. PRE-RADIATION ELECTRICAL

All 39 devices were functionally and parameterically working prior to irradiation and were inside the 25^{o}C spec limits for all parameters included in the test. Also, all 39 devices passed group A qualification tests. Refer to Appendix D for select parameters pre-irradiation data.

VII. TEST SETUP AND PROCEDURE

A. Test Environment

Samples were enclosed in a lead/aluminum container vertically aligned with the source of radiation while being irradiated. Ambient temperature at the time of irradiation was 25^{o}C. Teradyne A360 automated tester used for electrical testing was maintained at 25^{o}C. All devices remained approximately at 25^{o}C while transporting from the irradiation site to the electrical test facility.

B. Biasing

Devices were biased by $\pm$15V power supplies during irradiation. Figure 1 outlines the bias circuit.

[2] Military Data Sheet
[3] Reliability Processing Instructions, see Sec.-3

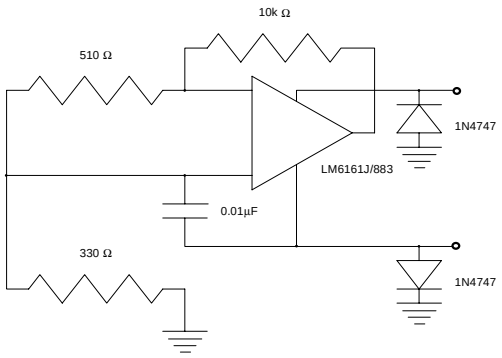


Figure 1: Bias Circuit

C. Exposure Time

Exposure times were calculated from the decay rate on the day of exposure. Decay rate was calculated by exponential decay formula using the decay rate at the time of last calibration of Gammacell 220.

D. Dose Rate

Devices were exposed per condition A of MIL-STD-883D method 1019.4. The Gammacell 220 currently does not have the capability to test devices under condition B. Exact values of dose rate on the day of the exposure were tabulated at the time of last qualification. Dose rate on 4 Aug 1995 was 144.6 Rads/sec and 143.6 Rads/sec on 21 Aug 1995.

E. Handling While Transporting Devices

All devices were open circuited while transporting to the Teradyne A360 electrical tester. Electrical characterization was completed within 15-20 minutes after each irradiation step.

F. Electrical Tests

Remote/Not-in-flux electrical tests were performed on the irradiated devices using Teradyne automated tester A360. Biasing and other circuit configuration while electrically testing varied depending on the test. Refer to Appendix B and C for more information about individual tests.

VIII. SUMMARY DATA TABLES

Summaries of select parameters after each step of irradiation are presented in Appendix D. These tables show the room temperature upper and lower spec limits (if applicable), average, minimum, maximum values and the standard deviation of the parameter for the sample devices. Irradiation rate was approximately 143.9 Rads/sec. Data for the parameters not included in the summary tables is also available.

IX. SELECT GRAPHS

Graphs showing the trends in individual parameters are shown in Appendix C. Average values of each parameter is plotted as a function of total dose. Range for the sample devices is also included on the graphs. Upper and lower room temperature spec limits and hot/cold limits are shown only for reference. In addition to the graphs, all data values are tabulated and any special test conditions are also outlined.

APPENDIX A

DEFINITIONS

Ionizing Radiation Effects:

The changes in the electrical parameters of a device or integrated circuit resulting from radiation induced charge. Also known as Total Dose Effects.

In-Flux Testing:

Electrical measurements made on devices during irradiation exposure

Not-In-Flux Testing:

Electrical measurements made on devices at any time other than during irradiation

Rads (Si):

The quantity of ionizing energy that will impart 100 ergs of energy to one gram of silicon.

Remote tests:

Electrical tests on devices which are physically removed from the radiation location.

Time Dependent Effects:

Significant degradation in electrical parameters caused by the growth or annealing or both of radiation-induced trapped charge after irradiation. Similar effects also take place during irradiation.

APPENDIX B

ELECTRICAL PARAMETER LIST & SUMMARY

Test	Parameter	%Δ[4]
10.	Power Supply Current	-8.0
11.	Positive Swing Voltage $V_S = \pm 12V, V_{IN+}=1V, V_{IN-}=0V$	-0.8
12.	Positive Output Short Circuit Current	-19.6
13.	Negative Output Short Circuit Current	-26.7
14.	Negative Swing Voltage $V_S = \pm 12V, V_{IN+}=0V, V_{IN-}=1V$	-1.3
15.	Positive Swing Voltage $V_{S+}=5V$, $V_{S-}=0V$, $V_{IN+}=2V, V_{IN-}=2.5V$	1.2
16.	Positive Swing Voltage $V_{S+}=5V$, $V_{S-}=0V$, $V_{IN+}=3V, V_{IN-}=2.5V$	-2.4
17.	Input Offset Voltage	126.5
18.	Input Bias Current	299.7
19.	Input Offset Current	-528.8
20.	Positive Gain	-65.5
21.	Negative Gain	-60.4
22.	Total Gain	-62.7
23.	Common Mode Rejection Ratio V_{CM}=10V TO -10V	-12.3
24.	Common Mode Rejection Ratio V_{CM}=13.9V TO -12.9V	-12.8
25.	Positive Common Mode Voltage Range V_{CM}=12.9V TO 13.9V	-525.5
26.	Negative Common Mode Voltage Range V_{CM}=-11.9V TO -12.9V	429.1
27.	Positive Common Mode Voltage Range $V_{S+}=5V$, $V_{S-}=0V$, V_{CM}=2.9V TO 3.9V	859.2
28.	Negative Common Mode Voltage Range $V_{S+}=5V$, $V_{S-}=0V$, V_{CM}=3V TO 2V	-46.3
30.	Power Supply Rejection Ratio	-10.4
33.	Gain Bandwidth	-6.2
34.	Positive Slew Rate	-11.0
35.	Negative Slew Rate	-11.1
36.	Average Slew Rate	-11.0

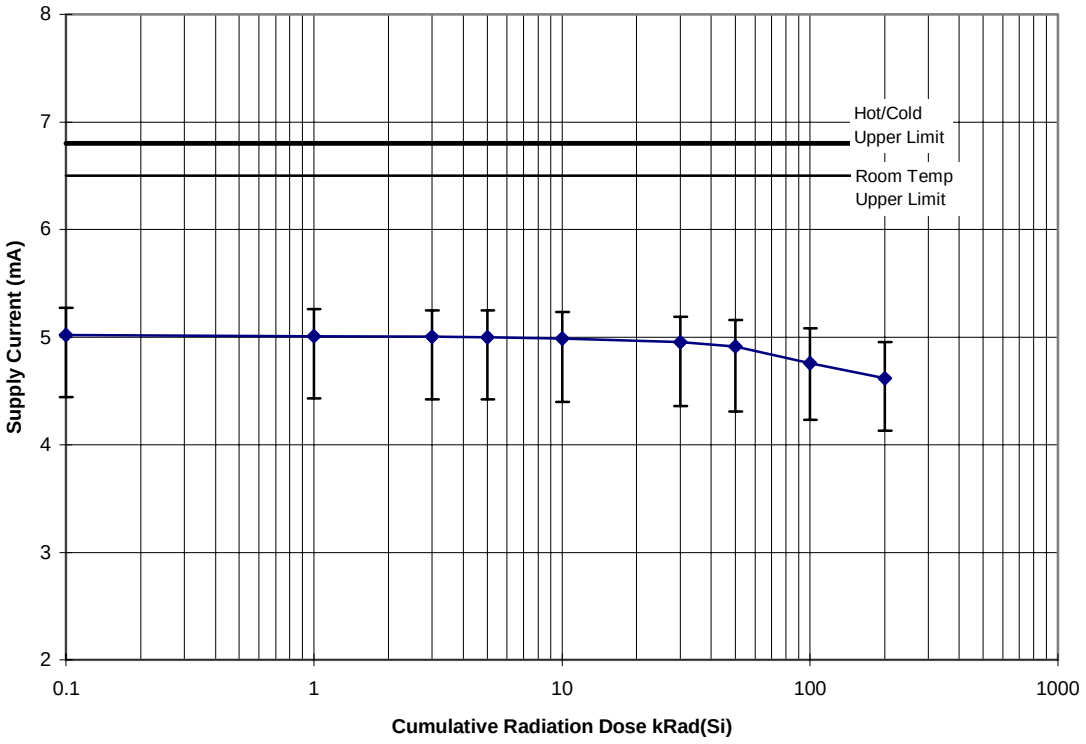
[4] Percent change in the average parameter value between pre-rad and post 200k rad exposure

APPENDIX C
LM6161J/883 Characteristics
Supply Current

Conditions

25°C MDS Limits
Upper = 6.5 mA
Lower = N/A
125/-55°C MDS Limits
Upper = 6.8 mA
Lower = N/A
T_A = 25°C
Irradiation Rate = 143.9 Rads/sec

Radiation Dose kRad(Si)	Supply Current (mA) N= 39				
	Average	Min	Max	Range	St. Dev.
0.1	5.018	4.440	5.270	0.830	0.232
1	5.011	4.430	5.260	0.830	0.234
3	5.004	4.420	5.250	0.830	0.234
5	4.998	4.420	5.250	0.830	0.234
10	4.987	4.400	5.230	0.830	0.236
30	4.951	4.360	5.190	0.830	0.242
50	4.911	4.310	5.160	0.850	0.247
100	4.756	4.230	5.080	0.850	0.242
200	4.615	4.130	4.950	0.820	0.257

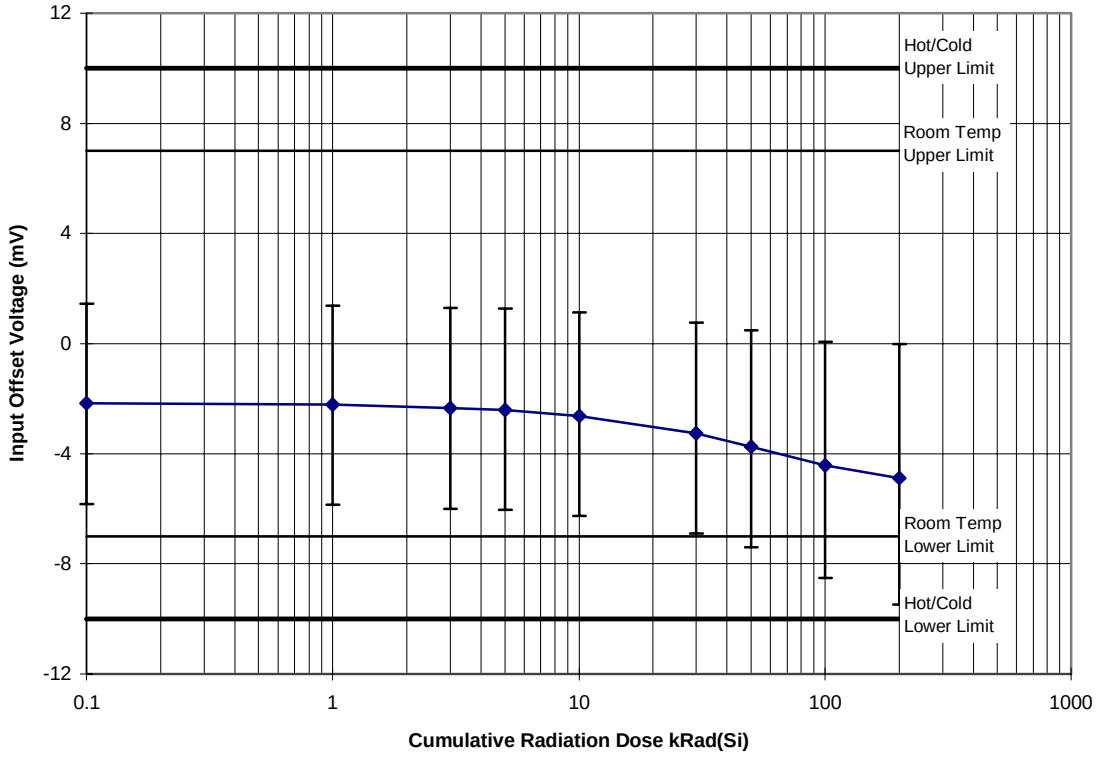


APPENDIX C
LM6161J/883 Characteristics
Input Offset Voltage

Conditions

25°C MDS Limits
Upper = 7 mV
Lower = -7 mV
125/-55°C MDS Limits
Upper = 10mV
Lower = -10mV
T_A = 25°C
Irradiation Rate = 143.9 Rads/sec

Radiation Dose kRad(Si)	Input Offset Voltage (mV) N= 39				
	Average	Min	Max	Range	St. Dev.
0.1	-2.159	-5.830	1.440	7.270	1.938
1	-2.211	-5.850	1.380	7.230	1.921
3	-2.335	-6.000	1.290	7.290	1.927
5	-2.414	-6.050	1.270	7.320	1.928
10	-2.629	-6.260	1.130	7.390	1.929
30	-3.253	-6.900	0.770	7.670	1.973
50	-3.736	-7.410	0.490	7.900	2.058
100	-4.414	-8.510	0.070	8.580	2.231
200	-4.891	-9.490	-0.030	9.460	2.602



APPENDIX C
LM6161J/883 Characteristics
Input Bias Current

Conditions

25°C MDS Limits
- Upper = 3 µA
- Lower = -3 µA

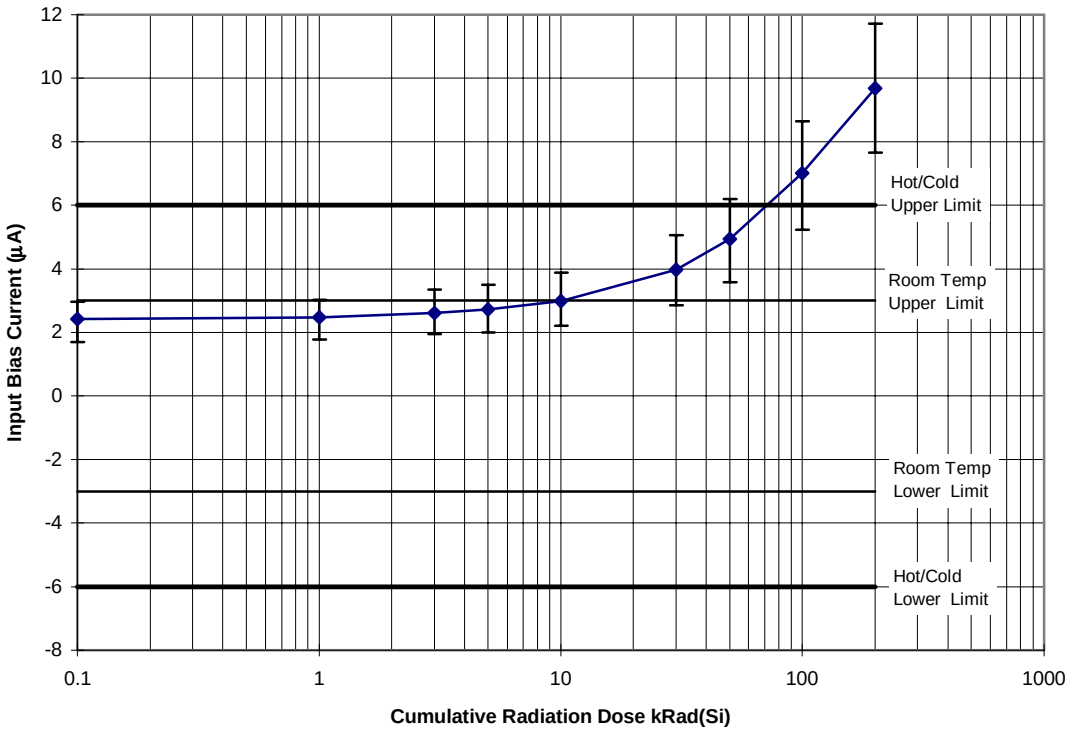
125/-55°C MDS Limits
- Upper = 6 µA
- Lower = -6 µA

T_A = 25°C

R_S = 10kΩ

Irradiation Rate = 143.9 Rads/sec

Radiation Dose kRad(Si)	Input Bias Current (µA) N= 39				
	Average	Min	Max	Range	St. Dev.
0.1	2.425	1.701	2.975	1.274	0.383
1	2.478	1.781	3.028	1.247	0.392
3	2.612	1.946	3.338	1.392	0.413
5	2.723	2.007	3.498	1.491	0.430
10	2.992	2.200	3.872	1.672	0.454
30	3.982	2.849	5.049	2.200	0.551
50	4.934	3.567	6.192	2.625	0.678
100	7.018	5.227	8.638	3.411	0.963
200	9.693	7.648	11.724	4.076	1.274



APPENDIX C
LM6161J/883 Characteristics
Input Offset Current

Conditions

25°C MDS Limits
- Upper = .35 µA
- Lower = -.35 µA

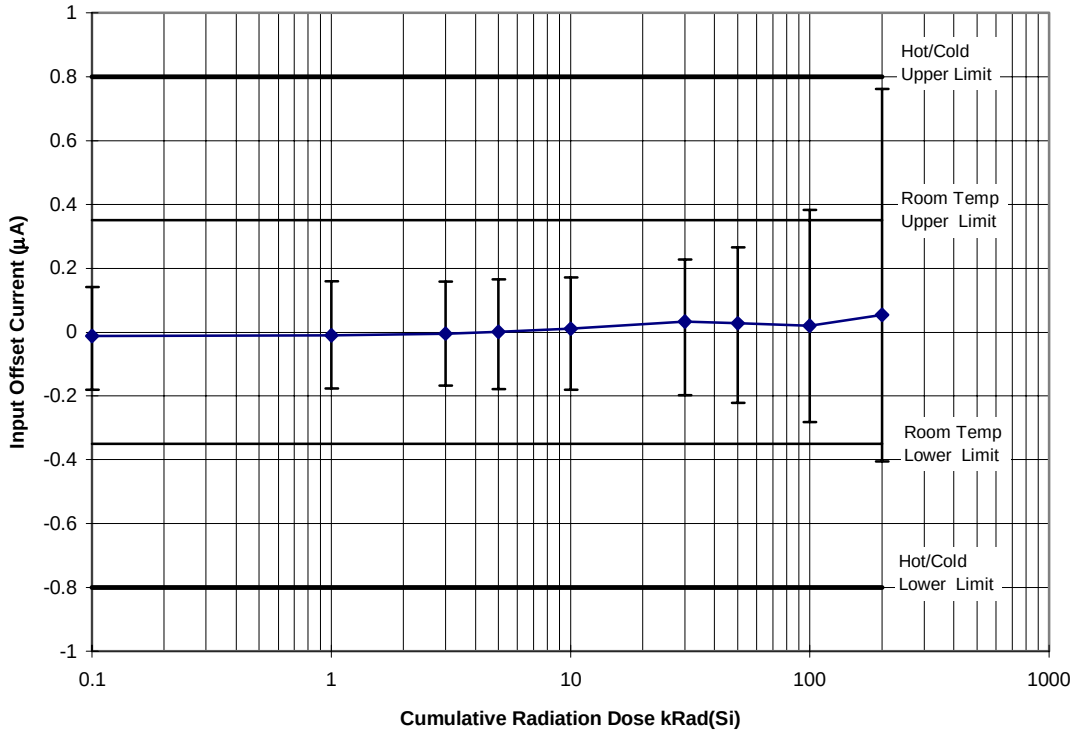
125/-55°C MDS Limits
- Upper = .8 µA
- Lower = -.8 µA

T_A = 25°C

R_S = 10kΩ

Irradiation Rate = 143.9 Rads/sec

Radiation Dose kRad(Si)	Input Offset Current (µA) N= 39				
	Average	Min	Max	Range	St. Dev.
0.1	-0.013	-0.181	0.140	0.321	0.059
1	-0.010	-0.176	0.159	0.335	0.059
3	-0.004	-0.167	0.158	0.325	0.060
5	0.001	-0.178	0.165	0.343	0.064
10	0.011	-0.181	0.171	0.352	0.069
30	0.033	-0.198	0.227	0.425	0.091
50	0.028	-0.222	0.266	0.488	0.108
100	0.019	-0.282	0.382	0.664	0.154
200	0.055	-0.405	0.762	1.167	0.301



APPENDIX C
LM6161J/883 Characteristics
Common Mode Rejection Ratio

Conditions

25°C MDS Limits

Upper = N/A

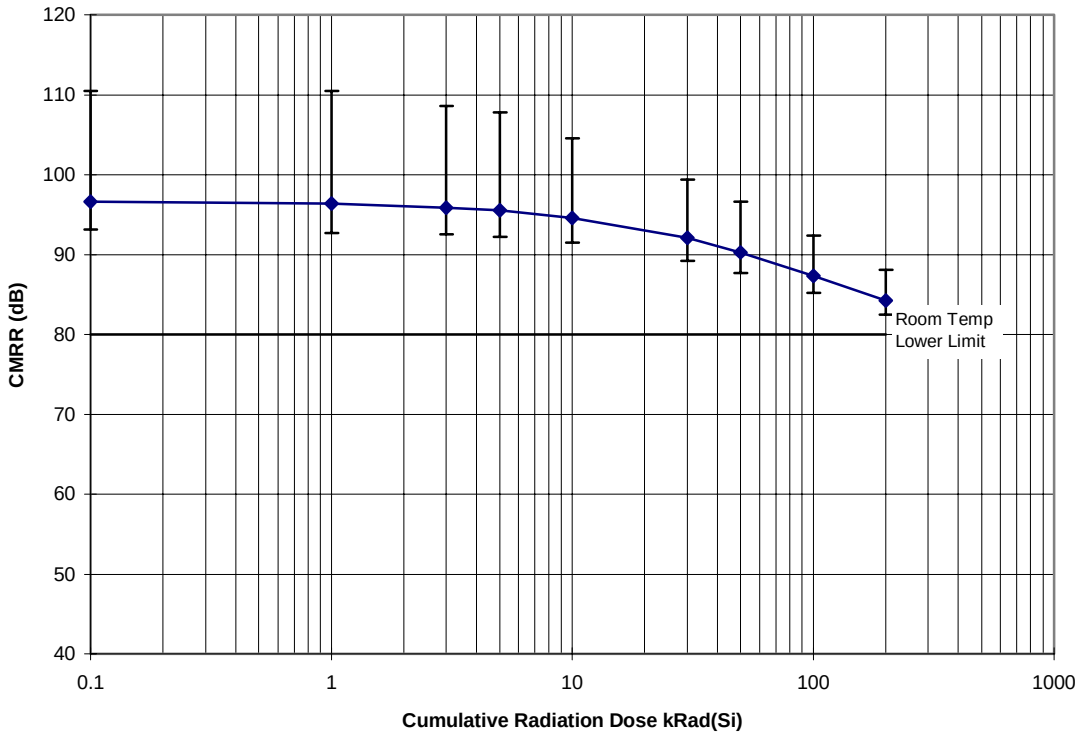
Lower = 80 dB

T_A = 25°C

V_{CM} = 13.9V TO -12.9V

Irradiation Rate = 143.9 Rads/sec

Radiation Dose kRad(Si)	Common Mode Rejection Ratio (dB) N= 39				
	Average	Min	Max	Range	St. Dev.
0.1	96.577	93.100	110.500	17.400	3.700
1	96.400	92.700	110.500	17.800	3.716
3	95.879	92.500	108.600	16.100	3.457
5	95.541	92.200	107.800	15.600	3.451
10	94.585	91.500	104.500	13.000	3.032
30	92.100	89.200	99.400	10.200	2.715
50	90.297	87.700	96.600	8.900	2.461
100	87.297	85.200	92.400	7.200	2.010
200	84.215	82.500	88.100	5.600	1.597

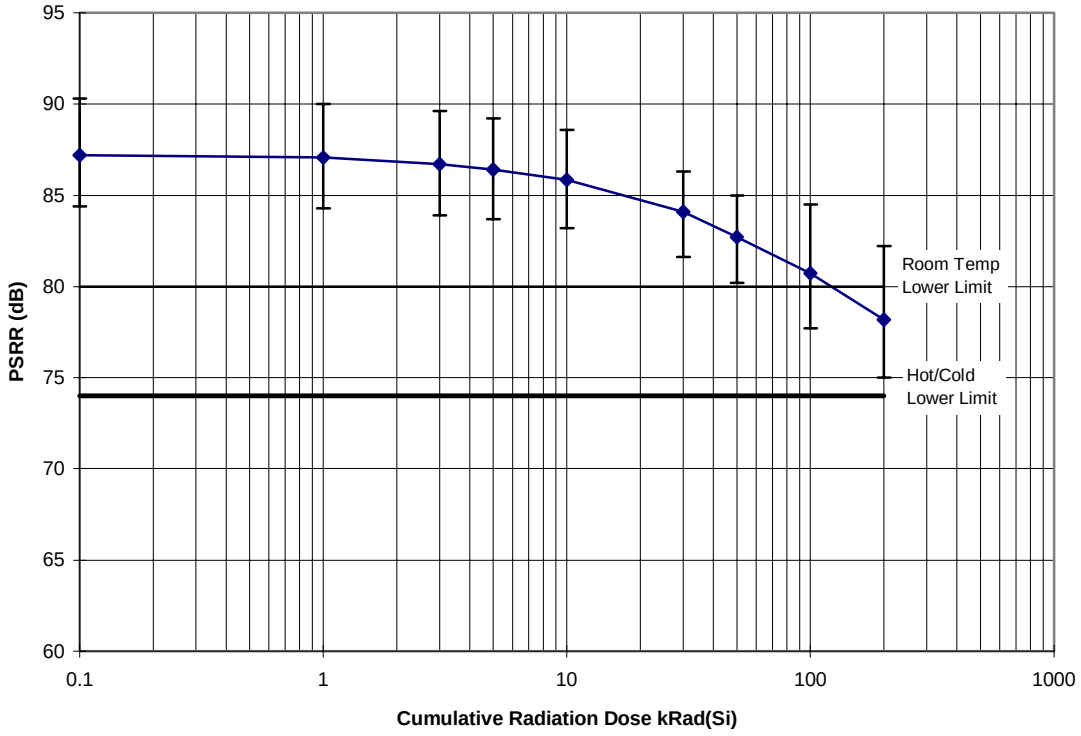


APPENDIX C
LM6161J/883 Characteristics
Power Supply Rejection Ratio

Conditions

25°C MDS Limits
Upper = N/A
Lower = 80 dB
125/-55°C MDS Limits
Upper = N/A
Lower = 74 dB
T_A = 25°C
V_S = +/-16V TO +/- 10V
Irradiation Rate = 143.9 Rads/sec

Radiation Dose kRad(Si)	Power Supply Rejection Ratio (dB) N= 39				
	Average	Min	Max	Range	St. Dev.
0.1	87.192	84.400	90.300	5.900	1.556
1	87.067	84.300	90.000	5.700	1.536
3	86.713	83.900	89.600	5.700	1.527
5	86.421	83.700	89.200	5.500	1.503
10	85.851	83.200	88.600	5.400	1.460
30	84.105	81.600	86.300	4.700	1.278
50	82.721	80.200	85.000	4.800	1.248
100	80.718	77.700	84.500	6.800	1.614
200	78.167	75.000	82.200	7.200	1.718



APPENDIX C
LM6161J/883 Characteristics
Gain

Conditions

25°C MDS Limits
- Upper = N/A
- Lower = 0.550k

125/-55°C MDS Limits
- Upper = N/A
- Lower = 0.330k

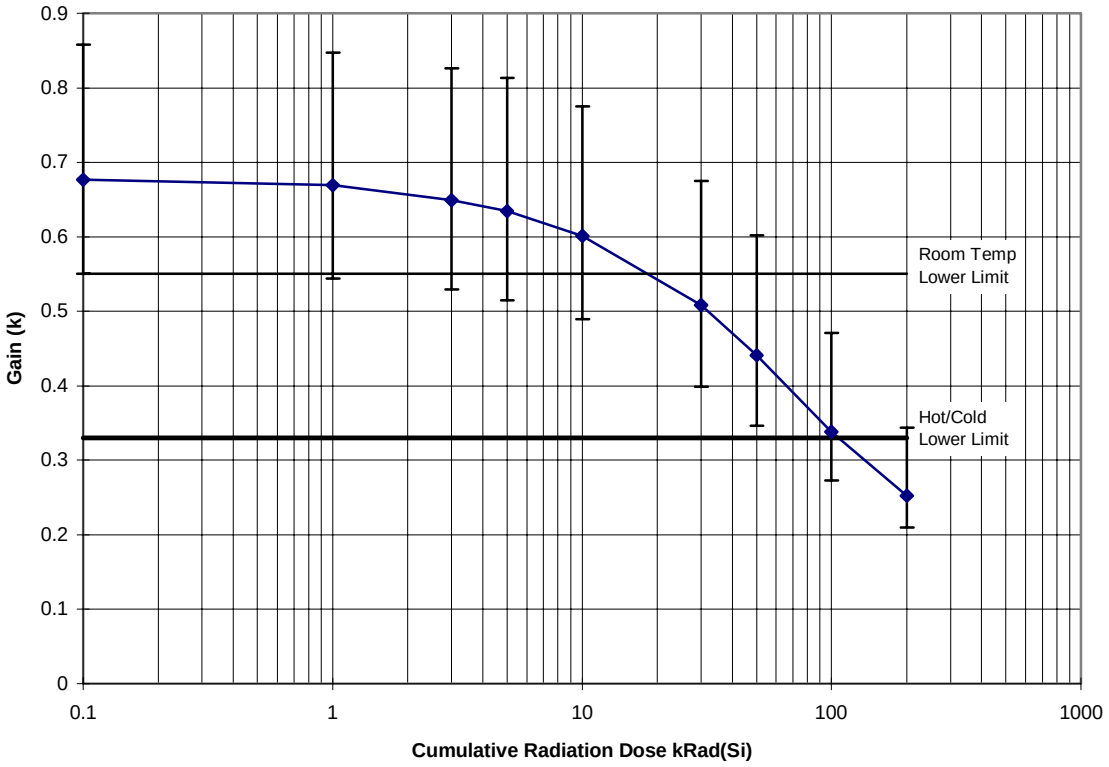
T_A = 25°C

V_{OUT} = +10V TO -10V

R_L = 2kΩ

Irradiation Rate = 143.9 Rads/sec

Radiation Dose kRad(Si)	Gain (k) N= 39				
	Average	Min	Max	Range	St. Dev.
0.1	0.677	0.550	0.858	0.308	0.082
1	0.669	0.544	0.847	0.303	0.082
3	0.649	0.529	0.826	0.297	0.080
5	0.634	0.515	0.813	0.298	0.081
10	0.601	0.490	0.775	0.285	0.079
30	0.508	0.399	0.675	0.276	0.078
50	0.441	0.346	0.602	0.256	0.070
100	0.339	0.273	0.471	0.198	0.052
200	0.252	0.210	0.344	0.134	0.033



APPENDIX D

SUMMARY TABLES

Test	Parameter	QA Limits		Units	N=39			
		Lower	Upper		Average	Min	Max	Range
Pre RAD								
10	Supply Current	N/A	6.50	mA	5.018	4.440	5.270	0.830
17	Input Offset Voltage	-7.00	7.00	mV	-2.159	-5.830	1.440	7.270
18	Input Bias Current	-3.00	3.00	µA	2.425	1.701	2.975	1.274
19	Input Offset Current	-0.35	0.35	µA	-0.013	-0.181	0.140	0.321
22	Gain	0.55	N/A	k	0.677	0.550	0.858	0.308
24	Common Mode Rejection Ratio	80.00	N/A	dB	96.577	93.100	110.500	17.400
30	Power Supply Rejection Ratio	80.00	N/A	dB	87.192	84.400	90.300	5.900
1K RAD								
10	Supply Current	N/A	6.50	mA	5.011	4.430	5.260	0.830
17	Input Offset Voltage	-7.00	7.00	mV	-2.211	-5.850	1.380	7.230
18	Input Bias Current	-3.00	3.00	µA	2.478	1.781	3.028	1.247
19	Input Offset Current	-0.35	0.35	µA	-0.010	-0.176	0.159	0.335
22	Gain	0.55	N/A	k	0.669	0.544	0.847	0.303
24	Common Mode Rejection Ratio	80.00	N/A	dB	96.400	92.700	110.500	17.800
30	Power Supply Rejection Ratio	80.00	N/A	dB	87.067	84.300	90.000	5.700
3K RAD								
10	Supply Current	N/A	6.50	mA	5.004	4.420	5.250	0.830
17	Input Offset Voltage	-7.00	7.00	mV	-2.335	-6.000	1.290	7.290
18	Input Bias Current	-3.00	3.00	µA	2.612	1.946	3.338	1.392
19	Input Offset Current	-0.35	0.35	µA	-0.004	-0.167	0.158	0.325
22	Gain	0.55	N/A	k	0.649	0.529	0.826	0.297
24	Common Mode Rejection Ratio	80.00	N/A	dB	95.879	92.500	108.600	16.100
30	Power Supply Rejection Ratio	80.00	N/A	dB	86.713	83.900	89.600	5.700

APPENDIX D

SUMMARY TABLES

Test	Parameter	QA Limits		Units	N=39			
		Lower	Upper		Average	Min	Max	Range
5K RAD								
10	Supply Current	N/A	6.50	mA	4.998	4.420	5.250	0.830
17	Input Offset Voltage	-7.00	7.00	mV	-2.414	-6.050	1.270	7.320
18	Input Bias Current	-3.00	3.00	µA	2.723	2.007	3.498	1.491
19	Input Offset Current	-0.35	0.35	µA	0.001	-0.178	0.165	0.343
22	Gain	0.55	N/A	k	0.634	0.515	0.813	0.298
24	Common Mode Rejection Ratio	80.00	N/A	dB	95.541	92.200	107.800	15.600
30	Power Supply Rejection Ratio	80.00	N/A	dB	86.421	83.700	89.200	5.500
10K RAD								
10	Supply Current	N/A	6.50	mA	4.987	4.400	5.230	0.830
17	Input Offset Voltage	-7.00	7.00	mV	-2.629	-6.260	1.130	7.390
18	Input Bias Current	-3.00	3.00	µA	2.992	2.200	3.872	1.672
19	Input Offset Current	-0.35	0.35	µA	0.011	-0.181	0.171	0.352
22	Gain	0.55	N/A	k	0.601	0.490	0.775	0.285
24	Common Mode Rejection Ratio	80.00	N/A	dB	94.585	91.500	104.500	13.000
30	Power Supply Rejection Ratio	80.00	N/A	dB	85.851	83.200	88.600	5.400
30K RAD								
10	Supply Current	N/A	6.50	mA	4.951	4.360	5.190	0.830
17	Input Offset Voltage	-7.00	7.00	mV	-3.253	-6.900	0.770	7.670
18	Input Bias Current	-3.00	3.00	µA	3.982	2.849	5.049	2.200
19	Input Offset Current	-0.35	0.35	µA	0.033	-0.198	0.227	0.425
22	Gain	0.55	N/A	k	0.508	0.399	0.675	0.276
24	Common Mode Rejection Ratio	80.00	N/A	dB	92.100	89.200	99.400	10.200
30	Power Supply Rejection Ratio	80.00	N/A	dB	84.105	81.600	86.300	4.700

APPENDIX D

SUMMARY TABLES

Test	Parameter	QA Limits		Units	N=39			
		Lower	Upper		Average	Min	Max	Range
50K RAD								
10	Supply Current	N/A	6.50	mA	4.911	4.310	5.160	0.850
17	Input Offset Voltage	-7.00	7.00	mV	-3.736	-7.410	0.490	7.900
18	Input Bias Current	-3.00	3.00	µA	4.934	3.567	6.192	2.625
19	Input Offset Current	-0.35	0.35	µA	0.028	-0.222	0.266	0.488
22	Gain	0.55	N/A	k	0.441	0.346	0.602	0.256
24	Common Mode Rejection Ratio	80.00	N/A	dB	90.297	87.700	96.600	8.900
30	Power Supply Rejection Ratio	80.00	N/A	dB	82.721	80.200	85.000	4.800
100K RAD								
10	Supply Current	N/A	6.50	mA	4.756	4.230	5.080	0.850
17	Input Offset Voltage	-7.00	7.00	mV	-4.414	-8.510	0.070	8.580
18	Input Bias Current	-3.00	3.00	µA	7.018	5.227	8.638	3.411
19	Input Offset Current	-0.35	0.35	µA	0.019	-0.282	0.382	0.664
22	Gain	0.55	N/A	k	0.339	0.273	0.471	0.198
24	Common Mode Rejection Ratio	80.00	N/A	dB	87.297	85.200	92.400	7.200
30	Power Supply Rejection Ratio	80.00	N/A	dB	80.718	77.700	84.500	6.800
200K RAD								
10	Supply Current	N/A	6.50	mA	4.615	4.130	4.950	0.820
17	Input Offset Voltage	-7.00	7.00	mV	-4.891	-9.490	-0.030	9.460
18	Input Bias Current	-3.00	3.00	µA	9.693	7.648	11.724	4.076
19	Input Offset Current	-0.35	0.35	µA	0.055	-0.405	0.762	1.167
22	Gain	0.55	N/A	k	0.252	0.210	0.344	0.134
24	Common Mode Rejection Ratio	80.00	N/A	dB	84.215	82.500	88.100	5.600
30	Power Supply Rejection Ratio	80.00	N/A	dB	78.167	75.000	82.200	7.200

APPENDIX E

LM6161J/883 MILITARY DATA SHEET