SINGLE EVENT LATCH-UP TEST REPORT

PRODUCT:	AD8306AF/QMLR
DIE TYPE:	AD8306
DATE CODE:	1128
CASE TEMPERATURE:	125°C
EFFECTIVE LET:	87.85MeV-cm^2/mg
MINIMUM FLUENCE:	1E7 ion/cm^2
FLUX:	~1E5 ion/cm^2-s
FACILITIES:	Lawrence Berkeley National Laboratories
TESTED:	August 31, 2011

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ANALOG DEVICES

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Single Event Latchup Testing of the AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier for Analog Devices

Customer: Analog Devices (PO# 45352065)

RAD Job Number: 11-453

Part Types Tested: Analog Devices AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier. The units were irradiated on August 31st, 2011.

Traceability Information: Manufacturing Code: E193554; see a photograph of a sample unit-under-test in Appendix A for traceability information/part markings.

Quantity of Parts for Testing: Two units were exposed to a maximum fluence of 1E7ion/cm^2 at a maximum LET of approximately 88MeV-cm^2/mg using worst-case bias and temperature (125°C).

Pre-Irradiation Burn-In: Burn-in not specified by the customer.

Referenced Test Standard(s): ASTM F1192, EIA/JESD57

Electrical Test Conditions: Supply current monitored during exposure.

Test Software / Hardware: ICC.XLS, See Appendix C, Table C.1 for a list of test equipment and calibration dates.

Bias Conditions: All units-under-test were biased during heavy ion irradiation using a worst-case supply potential. See Section 4 and Appendix B for the details of the bias conditions.

Ion Energy and LET Ranges: Minimum of 10MeV/n Xe beam with a maximum effective LET of approximately 83MeV-cm^2/mg. The 10MeV/n Xe beam had a minimum range of approximately 60µm in silicon to the Bragg Peak (which is the shortest range particle used).

Heavy Ion Flux and Maximum Fluence Levels: Flux of approximately 1E5ions/cm^2. Minimum 1E7 ions/cm^2 per unit tested when no events were detected.

Facility and/or Radiation Source: Lawrence Berkeley National Laboratories (LBNL) Berkeley, CA (10MeV/n beam).

Irradiation Temperature: Maximum 125°C case temperature as specified as the worst-case condition by the customer.

The AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier is IMMUNE to SEL events to the maximum tested LET of approximately 88MeV-cm^2/mg and at a worst-case temperature of 125°C.

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1.0. Overview and Background

It is well known that heavy ion exposure can cause temporary and/or permanent damage in electronic devices. The damage can occur through various mechanisms including single event latch-up (SEL), single event burnout (SEB) and single event gate rupture (SEGR). An SEL event occurs when a parasitic npnp feedback latch structure becomes biased into the on state due to a dense track of electron-hole pairs created along the heavy ion path in silicon. This latch-up is self-sustaining since there is a positive feedback path created and requires a power cycle to reset. A single event latch-up can lead to single event burnout if the current draw from the SEL event is sufficient to damage the junction and/or bond wire. The damage is worse and/or becomes evident with increasing linear energy transfer (LET) and fluence. The two test standards usually used to govern this testing are ASTM F1192 and EIA/JESD57. This destructive testing is usually performed at the maximum datasheet voltage and temperature to a total fluence of not less than 1E7ion/cm^2.

2.0. Single Event Latch-Up Test Apparatus

The single event latch-up testing described in this final report was performed at the Lawrence Berkeley National Laboratories (LBNL) using the 88-Inch Cyclotron. The 88-Inch Cyclotron is operated by the University of California for the US Department of Energy (DOE) and is a K=140 sector-focused cyclotron with both light- and heavy-ion capabilities. Protons and other light-ions are available at high intensities (10-20pμA) up to maximum energies of 55 MeV (protons), 65 MeV (deuterons), 135 MeV (3He) and 140 MeV (4He). Most heavy ions through uranium can be accelerated to maximum energies, which vary with the mass and charge state.

For the SEL testing described in this final report the units-under-test were be placed in the Cave 4B vacuum chamber aligned with the heavy ion beam line. The test platter in the vacuum chamber has full x and y alignment capabilities along with 2-dimensional rotation, allowing for a variety of effective LETs for each ion. For SEE testing Lawrence Berkeley Laboratories provides the dosimetry via a local control computer running a Lab View based program. Each ion is calibrated just prior to use using five photomultiplier tubes (PMTs). Four of the five PMTS are used during the test to provide the beam statistics, while the center PMT is removed following calibration. Figure 2.1 shows an illustration of the LBL facility; including the location of Cave 4B, where the heavy ion SEE testing takes place.

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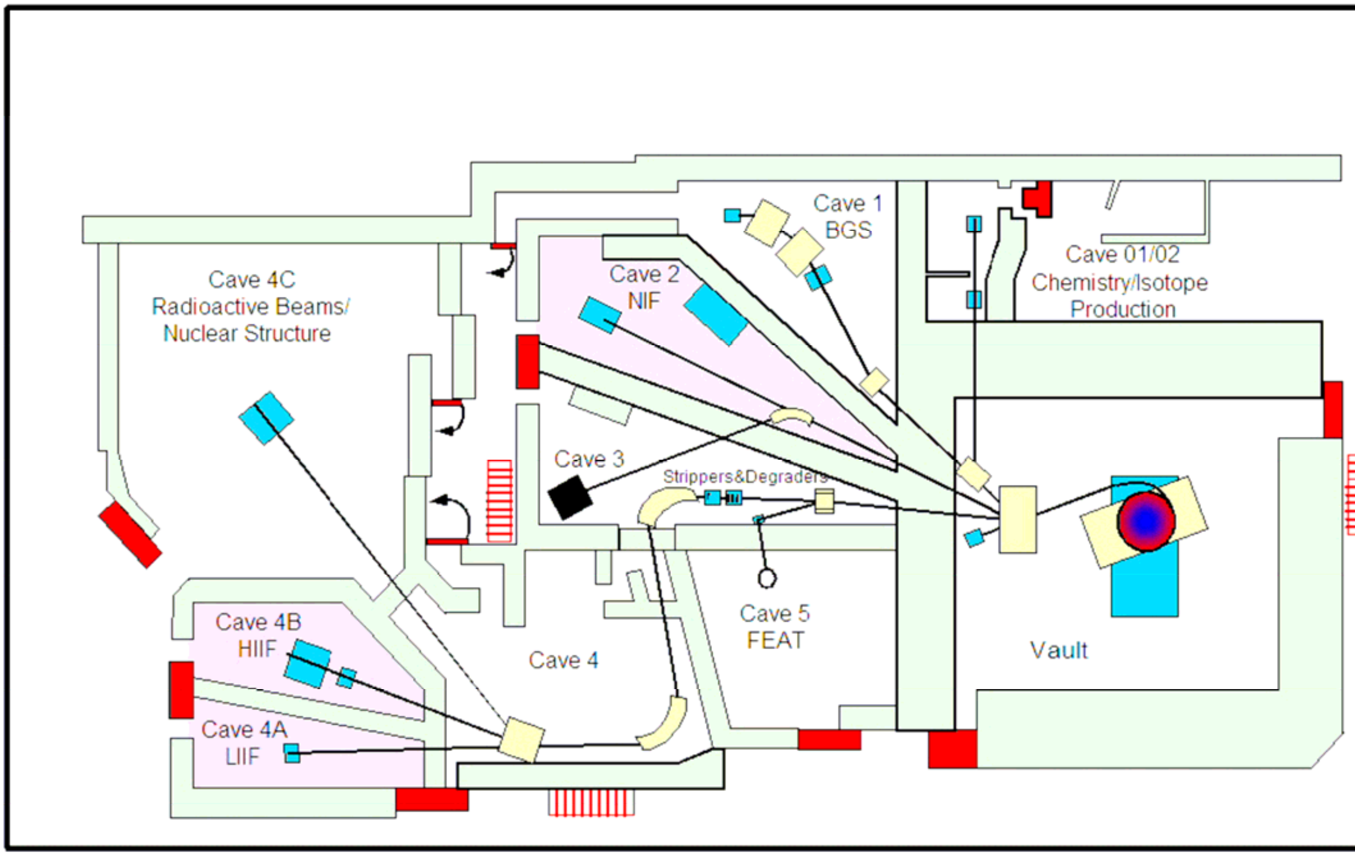

Figure 2.1. Map of 88-Inch Cyclotron Facility showing the location of Cave 4B, where the SEE testing was performed.

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3.0. Radiation Test Conditions

The AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier described in this final report was irradiated using the 10MeV/n Xe beam at the Lawrence Berkeley National Laboratory using a single sided supply potential of +6.5V and at the worst-case temperatures of 125°C (±5°C). Figure 3.1 shows the test board used for the SEL testing described in this final report (See the test circuit schematic in Appendix B for the additional details of the bias conditions). The test board was mounted on the test stage at Berkeley, which provided 3-axis of motion plus rotation. The board had multiple units-under-test that allowed for sequential testing of the units without vacuum breaks during testing. Additional features of the test board include:

1. Log Amps individually powered – power inputs filtered via RLC filters. (See top of site 1 schematic in Appendix B)
2. All 3 outputs (LMHi, LMLO, VLOG) are brought out for monitoring
3. Log Amp inputs held at steady-state cw rf signal during testing
4. Recommended (general application) value of RLIM = 400Ω tied from LMDR pin to ground.
5. VLOG output offset compensated. (Output range from +0.34 to +2.4V is shifted to 0V to 2.06V.)
6. Outputs are buffered with Gain = +2 (VLOG output at scope should range from 0V to 4.12V)

The 10MeV/n beam was used to provide sufficient range in silicon while meeting the maximum LET requirements of the program. The other beams available at Berkeley are the 4.5MeV/n beam and the 16MeV/n beam. The 4.5MeV/n beam does not provide sufficient range for destructive SEE testing while the 16MeV/n beam provides a much smaller selection of ions. Figure 3.2 shows the 10MeV/n beam characteristics for Xe. As seen in the figure, the range to the Bragg Peak is approximately 60µm while the surface LET is approximately 58MeV-cm2/mg for the Xe beam. Figure 3.3 shows the characteristics for all the beams available at Berkeley. Note that the units were de-encapsulated prior to testing and all exposures took place from the top surface providing a distance to the active layer in Silicon of approximately 5 to 10µm.

As noted above, the devices were irradiated to a minimum fluence of 1E7ion/cm^2. The flux varied during the testing, but was consistently targeted to approximately 1E5ion/cm^2-s, depending on the ion species and the response of the unit-under-test. The irradiation of the units-under-test continued until either the minimum fluence was reached or a latchup event was observed.

For the elevated temperature portion of the single event latch-up testing an aluminum plate heater fixed to the back of the board and was used to heat the device-under-test (DUT) with an

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RTD used to monitor the temperature. The case temperature of the DUT was calibrated prior to the testing to the RTD with a thermocouple, allowing the RTD to provide feedback and maintain a calibrated case temperature (up to 125°C) throughout the testing. The data monitored during the test (case temperature, supply voltage and supply current) was routed to the control room (approximately 20-feet away) using shielded coaxial cable.

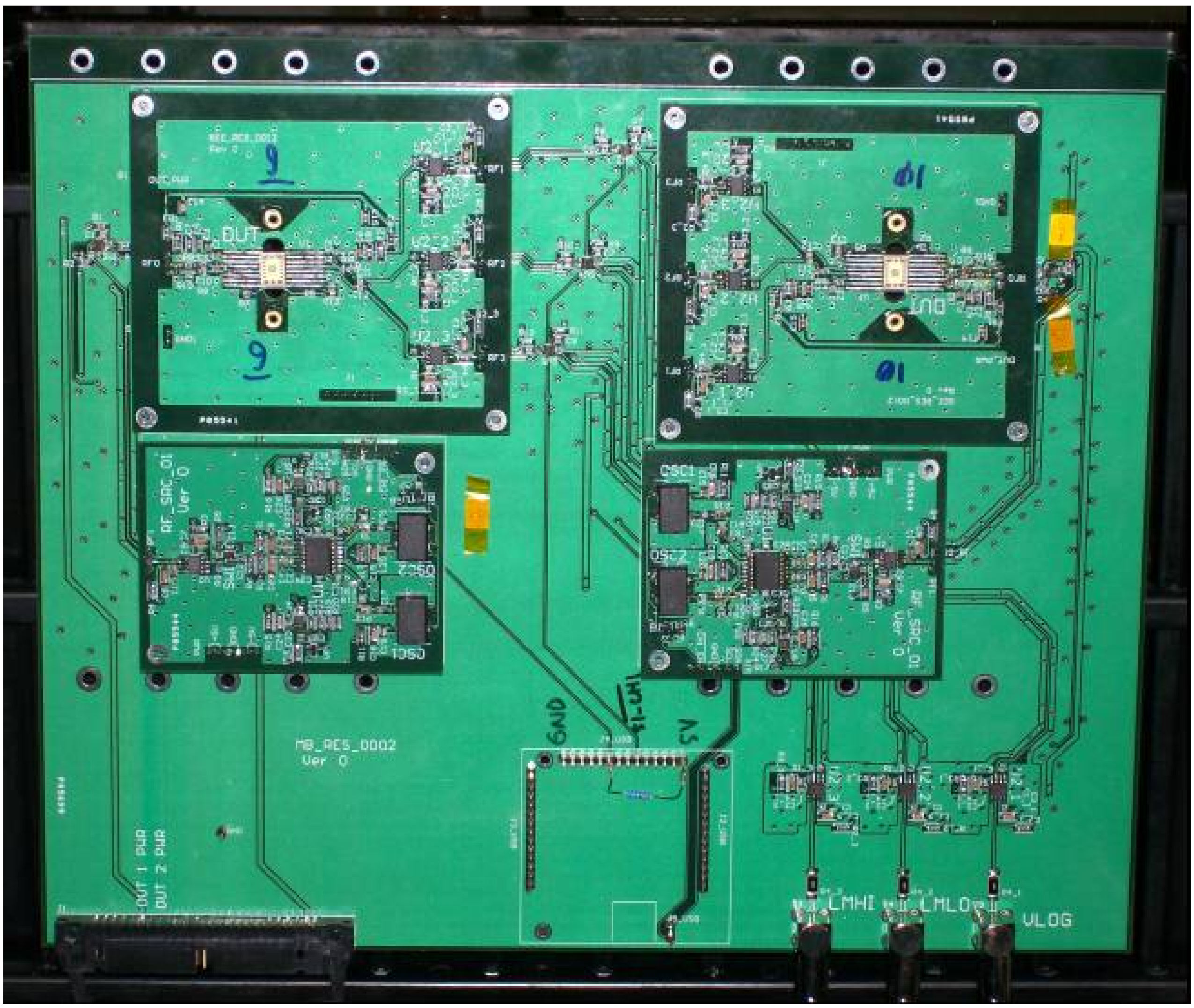

Figure 3.1. Single event test board prepared for mounting on the test stage at Berkeley. The board has two units-under-test mounted simultaneously to minimize vacuum breaks during testing. There is also a heater plate mounted to the backside of the board to provide the elevated temperature required for this testing.

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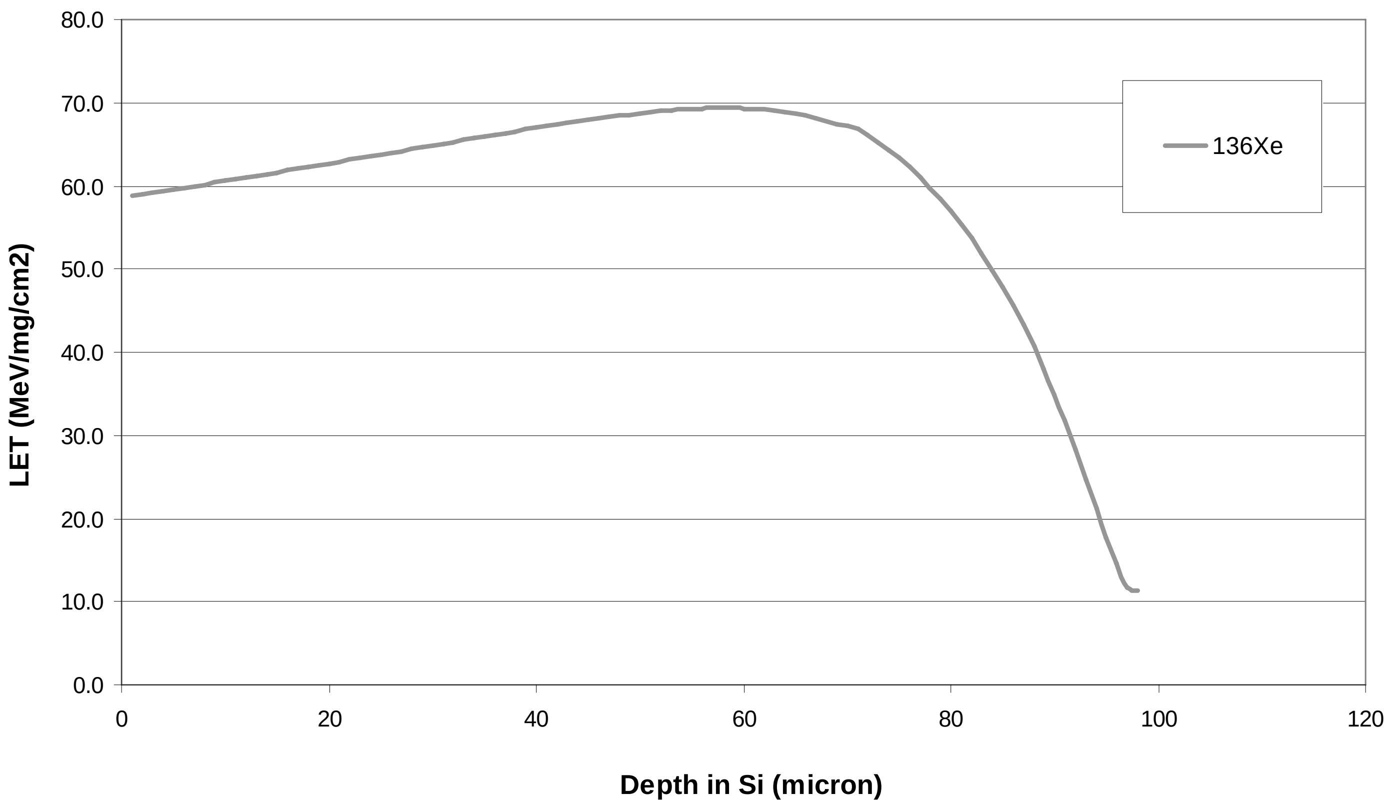

Figure 3.2. Range of the 10MeV/n Xe beam into silicon. The range to the Bragg Peak for Xe (the shortest range ion used) is approximately 60µm while the surface LET is approximately 58MeV-cm2/mg.

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Ion	Cocktail (MeV/nuc)	Energy (MeV)	Z	A	Chg. State	% Nat. Abund.	LET 0° (MeV/(mg/cm^2))	LET 60°	Range (µm)	Method
B	4.5	44.90	5	10	+2	19.9	1.65	3.30	78.5	MIVOC
N	4.5	67.44	7	15	+3	0.37	3.08	6.16	67.8	Gas
Ne	4.5	89.95	10	20	+4	90.48	5.77	11.54	53.1	Gas
Si[1]	4.5	139.61	14	29	+6	4.67	9.28	18.56	52.4	Gas
Ar	4.5	180.00	18	40	+8	99.6	14.32	28.64	48.3	Gas
V	4.5	221.00	23	51	+10	99.75	21.68	43.36	42.5	Probe
Cu	4.5	301.79	29	63	+13	69.17	29.33	58.66	45.6	Probe
Kr	4.5	387.08	36	84	+17	17.3	38.96	77.92	48.0	Gas
Y	4.5	409.58	39	89	+18	100	45.58	91.16	45.8	Probe
Ag	4.5	499.50	47	109	+22	48.161	58.18	116.36	46.3	Probe
Xe	4.5	602.90	54	136	+27	8.9	68.84	137.68	48.3	Gas
Tb	4.5	724.17	65	159	+32	100	77.52	155.04	52.4	Probe
Ta	4.5	805.02	73	181	+36	99.988	87.15	174.30	53.0	Probe
Bi	4.5	904.16	83	209	+41	100	99.74	199.48	52.9	Oven
B	10	108.01	5	11	+3	80.1	0.89	1.78	305.7	MIVOC
O	10	183.47	8	18	+5	0.2	2.19	4.38	226.4	Gas
Ne	10	216.28	10	22	+6	9.25	3.49	6.98	174.6	Gas
Si[1]	10	291.77	14	29	+8	4.67	6.09	12.18	141.7	Gas
Ar	10	400.00	18	40	+11	99.6	9.74	19.48	130.1	Gas
V	10	508.27	23	51	+14	99.75	14.59	29.18	113.4	Probe
Cu	10	659.19	29	65	+18	30.83	21.17	42.34	108.0	Probe
Kr	10	906.45	36	84	+24	57	30.23	60.46	113.1	Gas
Y	10	928.49	39	89	+25	100	34.73	69.46	102.2	Probe
Ag	10	1039.42	47	107	+29	51.839	48.15	96.30	90.0	Probe
Xe	10	1232.55	54	124	+34	0.1	58.78	117.56	90.0	Gas
N	16	233.75	7	14	+5	99.63	1.16	2.32	505.9	Gas
O	16	277.33	8	17	+6	0.04	1.54	3.08	462.4	Gas
Ne	16	321.00	10	20	+7	90.48	2.39	4.78	347.9	Gas
Si[1]	16	452.10	14	29	+10	4.67	4.56	9.12	274.3	Gas
Cl	16	539.51	17	35	+12	75.77	6.61	13.22	233.6	Natural
Ar	16	642.36	18	40	+14	99.600	7.27	14.54	255.6	Gas
V	16	832.84	23	51	+18	99.750	10.90	21.80	225.8	Probe
Cu	16	1007.34	29	63	+22	69.17	16.53	33.06	190.3	Probe
Kr	16	1225.54	36	78	+27	0.35	24.98	49.96	165.4	Gas
Xe	16	1954.71	54	124	+43	0.1	49.29	98.58	147.9	Gas
N	30	425.45	7	15	+7	0.37	0.76	1.52	1370.0	Gas
O	30	490.22	8	17	+8	0.04	0.98	1.96	1220.0	Gas
Ne	30	620.00	10	21	+10	0.27	1.48	2.96	1040.0	Gas
Ar	30	1046.11	18	36	+17	0.337	4.87	9.74	578.1	Gas

[1]By Special request

Figure 3.3. Characteristics of all the beams available at Berkeley. For the testing discussed in this report the 10MeV/n beam was used exclusively.

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4.0. Tested Parameters

During heavy ion exposure the supply current to the unit-under-test was measured and recorded in approximately 1-second increments. A plot of the supply currents versus time/fluence for each of the heavy ion exposures is included in this final report (see Section 5, "Single Event Latch-Up Test Results"). In addition to the supply current, the V_{LOG} output (see the functional block diagram of the unit-under-test in Appendix B) of the unit-under-test was also measured to ensure proper operation/output level before, during and after the run. The units were run dynamically with a 5MHz signal on the clock in pin with the V_{LOG} output captured on a digitizing oscilloscope. Note that the output transients are reported separately in a report entitled "Single Event Transient Testing of the AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier for Analog Devices". However, as noted above for the SEL portion of the testing we did verify proper operation and/or recovery of the device using an oscilloscope that triggered whenever there was a significant distortion in the V_{LOG} pin.

Table 4.1 summarizes the single event transient tests performed for the AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier. The table records the total effective fluence, the average flux, the run time, the beam energy, the ion and the effective LET. As noted above, the SEL testing occurred at three case temperatures of approximately 125°C (±5°C).

In general the following minimum criteria must be met for a device to have considered passing the SEL test for a given ion, LET and/or temperature: during the heavy ion exposure the DUT's supply current must remain within the unit's specification limit without cycling power. If this condition is not satisfied following the heavy ion testing, then the SEL testing could be logged as a failure. Note that during heavy ion testing a substantial amount of total dose can be absorbed by the units-under-test. If a functional failure occurs during or following the testing, it is important to separate TID failures from destructive single event effects. Also, a single event latch-up may not be a "destructive" event since it is still functional, however a unit which experiences an SEL (i.e., a high sustained supply current requiring a power cycle to recover) is considered to have failed this test even if the units are functional and meet parametric limits following the testing.

For the testing described in this report the following general test procedure was used:

1. Turn on DUT power (+6.5V)
2. Set RF input Frequency to 5MHz
3. Select DUT via USB addressing
4. Slowly vary input amplitude
5. Observe VLOG output (J5) using scope or multimeter
6. Set RF input amplitude to obtain 4V (2V from DUT VLOG output)
7. Adjust temperature to +125°C
8. Turn ON ion beam, observe/monitor/log device current
9. Repeat process with different ion energies as device response dictates

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Table 4.1. Summary of the single event latch-up test runs for the Analog Devices AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier.

Run #	DUT	Temp (degC)	Total Eff Fluence	Average Flux	Beam	Ion	Eff LET	Angle
157	DUT1	27	1.01E+07	8.88E+04	10 MeV	Xe 58.78	58.78	0
158	DUT1	27	1.01E+07	9.13E+04	10 MeV	Xe 58.78	87.85	48
159	DUT1	85	1.00E+07	9.22E+04	10 MeV	Xe 58.78	87.85	48
160	DUT1	125	1.01E+07	7.63E+04	10 MeV	Xe 58.78	87.85	48
161	DUT2	29	2.12E+06	8.33E+04	10 MeV	Xe 58.78	87.85	48
162	DUT2	85	1.00E+07	7.92E+04	10 MeV	Xe 58.78	87.85	48
163	DUT2	125	1.00E+07	8.46E+04	10 MeV	Xe 58.78	87.85	48
164	DUT2	125	1.01E+07	9.26E+04	10 MeV	Xe 58.78	67.87	30
165	DUT2	125	1.01E+07	9.15E+04	10 MeV	Xe 58.78	58.78	0

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5.0. Single Event Latch-Up Test Results

The AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier (of the lot date code identified on the first page of this report) PASSED the SEL test with no significant events detected at the worst-case tested LET of 88MeV-cm^2/mg and at the worst-case temperature of 125°C. Further, the unit-under-test continued operating normally based on a check of the V_{LOG} output without the need to cycle power. Note that SET events were detected during the course of the SEL test and are reported in a separate report (as noted above). However the SET events were short lived and the unit returned to proper operation within a short period of time.

Table 5.1 show a summary of the single event latch-up data acquired. The table shows the part type (AD8306), the serial number of the part irradiated, the test configuration (all units irradiated with a 5MHz clock), the case temperature during testing, the ion species, the effective fluence, the effective LET and whether or not an SEL event occurred. Based on the total fluence received by each unit-under-test we can estimate that no device received more that 10krad(Si) of total ionizing dose (TID) during any run and, therefore, in our opinion TID damage did not play a significant role in these results.

Figures 5.1 through 5.4 show the supply current data during the SEL runs. In these figures the supply current is plotted as a function of time. The plots show the response of the unit-under-test from the start to the end of the exposure (See Table 5.1 for the fluence levels). As seen in these figures, the units-under-test show essentially no change in supply current during the course of the exposure indicating that no latchup events occurred.

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Table 5.1. Summary of the SEL test runs and results for the AD8306 5 MHz–400 MHz 100 dB High Precision

Run #	DUT	Temp (degC)	Total Eff Fluence	Beam	Ion	Eff LET	Comments
157	DUT1	27	1.01E+07	10 MeV	Xe 58.78	58.78	27C, no latch
158	DUT1	27	1.01E+07	10 MeV	Xe 58.78	87.85	27C, no latch
159	DUT1	85	1.00E+07	10 MeV	Xe 58.78	87.85	85C, no latch
160	DUT1	125	1.01E+07	10 MeV	Xe 58.78	87.85	125C, no latch
161	DUT2	29	2.12E+06	10 MeV	Xe 58.78	87.85	29C, no latch
162	DUT2	85	1.00E+07	10 MeV	Xe 58.78	87.85	85C, no latch
163	DUT2	125	1.00E+07	10 MeV	Xe 58.78	87.85	125C, no latch
164	DUT2	125	1.01E+07	10 MeV	Xe 58.78	67.87	125C, no latch
165	DUT2	125	1.01E+07	10 MeV	Xe 58.78	58.78	125C, no latch

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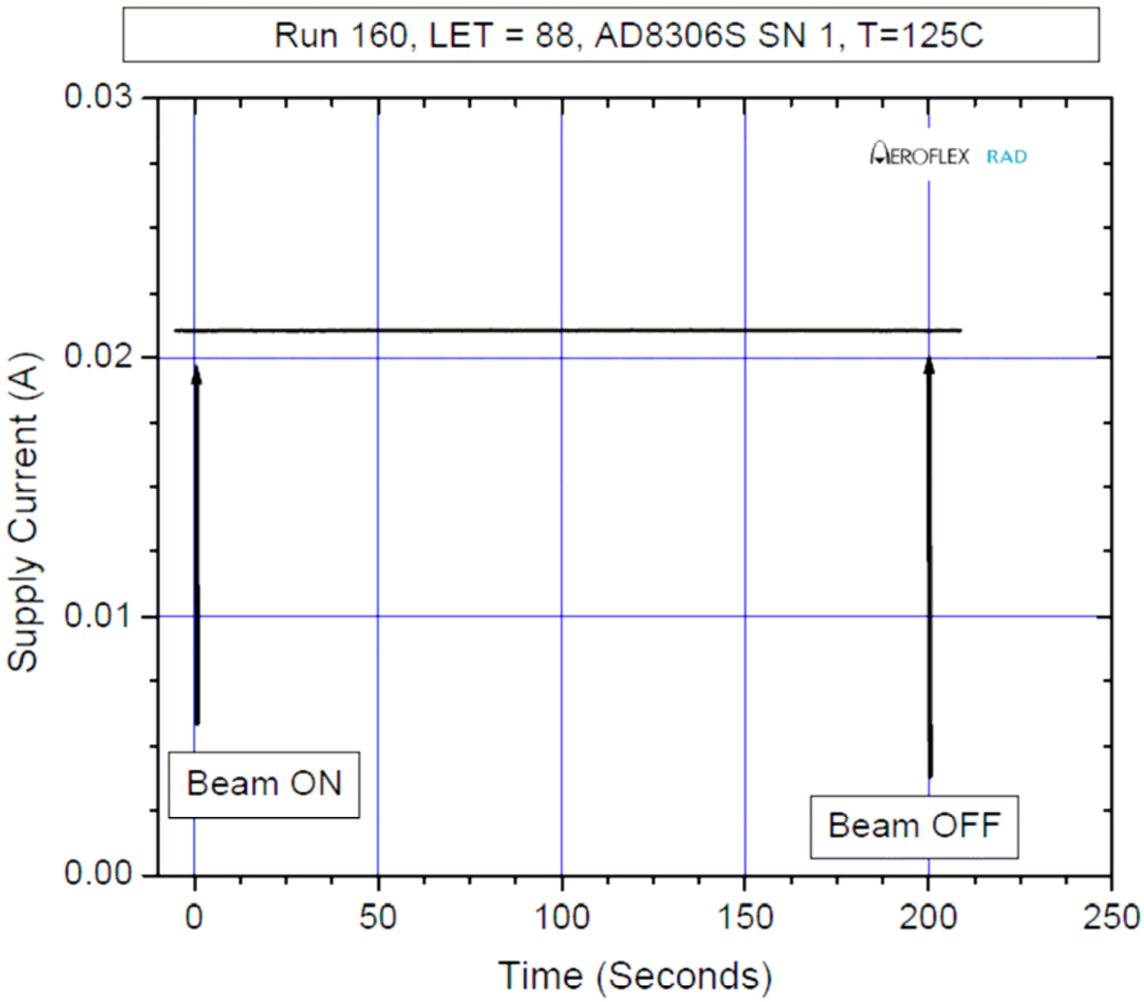

Figure 5.1. Input supply current versus time/fluence for the AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier (run 160). See Table 4.1 for the details of the test conditions.

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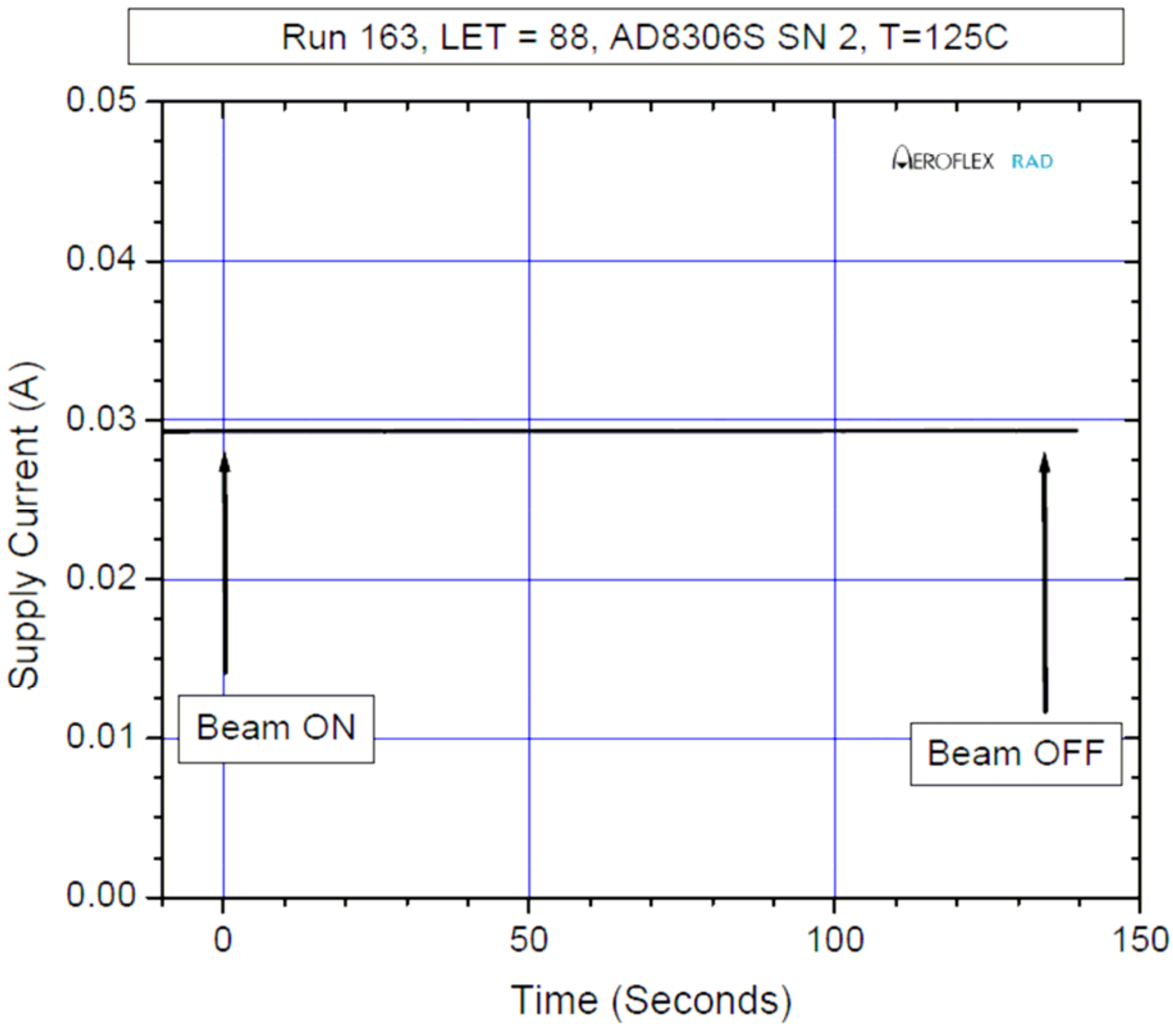

Figure 5.2. Input supply current versus time/fluence for the AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier (run 163). See Table 4.1 for the details of the test conditions.

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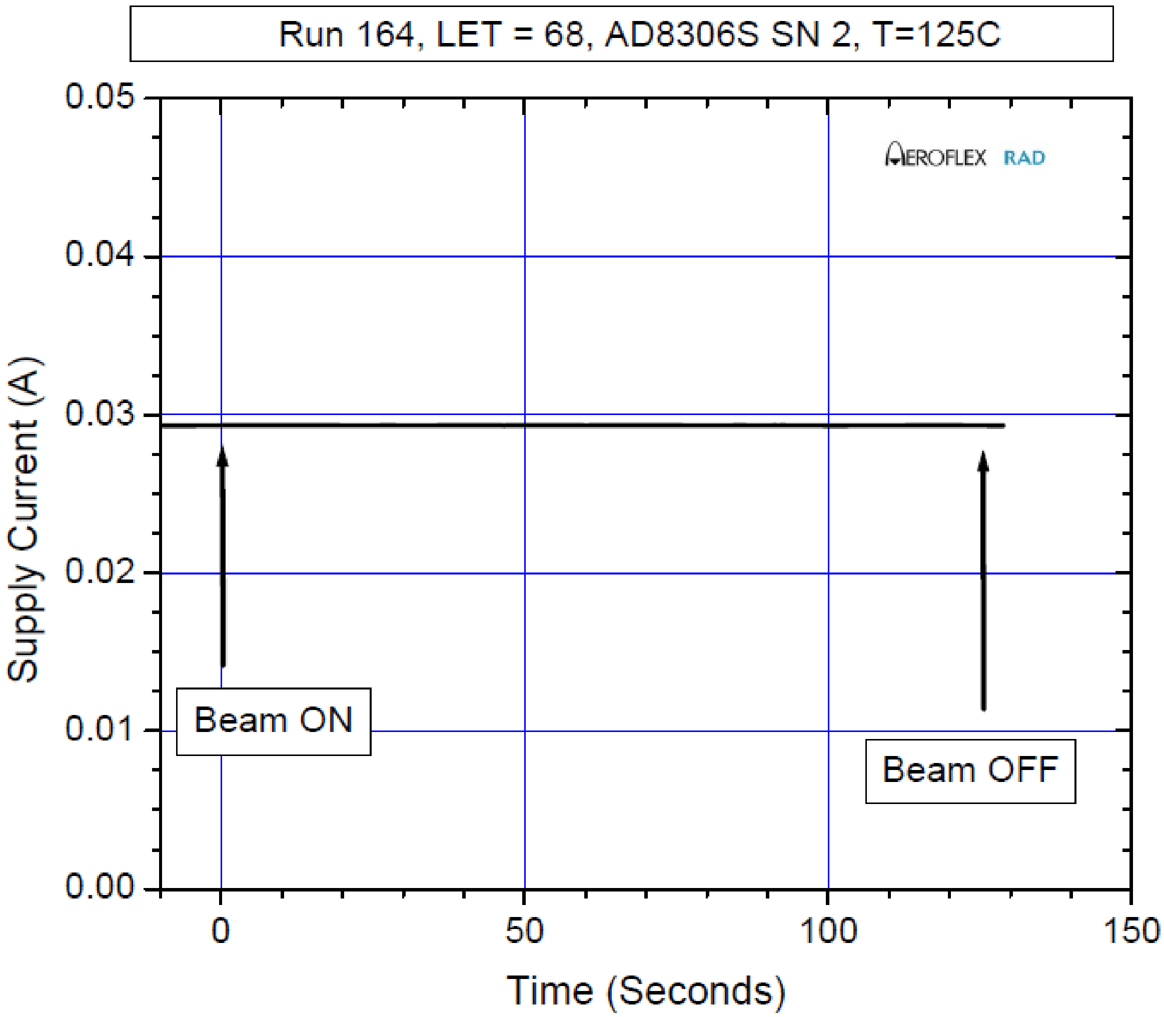

Figure 5.3. Input supply current versus time/fluence for the AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier (run 164). See Table 4.1 for the details of the test conditions.

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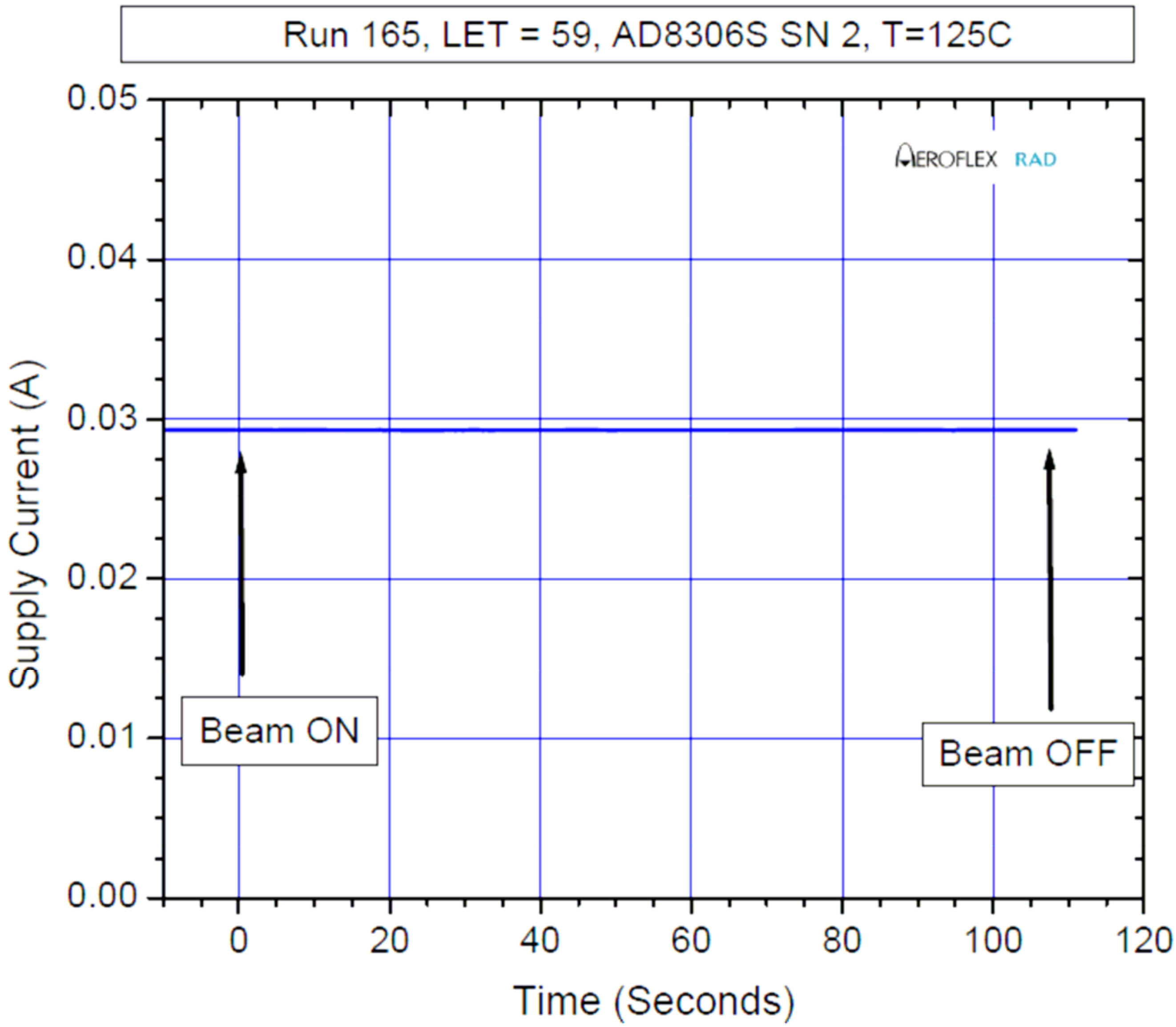

Figure 5.4. Input supply current versus time/fluence for the AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier (run 165). See Table 4.1 for the details of the test conditions.

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6.0. Summary/Conclusions

The single event latch-up testing described in this final report was performed at the Lawrence Berkeley National Laboratories (LBNL) using the 88-Inch Cyclotron. The 88-Inch Cyclotron is operated by the University of California for the US Department of Energy (DOE) and is a K=140 sector-focused cyclotron with both light- and heavy-ion capabilities. Protons and other light-ions are available at high intensities (10-20pμA) up to maximum energies of 55 MeV (protons), 65 MeV (deuterons), 135 MeV (3He) and 140 MeV (4He). Most heavy ions through uranium can be accelerated to maximum energies, which vary with the mass and charge state.

The AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier described in this final report was irradiated using a single sided supply potential of +6.5V and at the worst-case temperatures of 125°C (±5°C). During heavy ion exposure the supply current to the unit-under-test was measured and recorded in approximately 1-second increments. A plot of the supply currents versus time/fluence for each of the heavy ion exposures is included in this final report. In addition to the supply current, the V_{LOG} output of the unit-under-test was also measured to ensure proper operation/output level before, during and after the run. The units were run dynamically with a 5MHz signal on the clock in pin.

The AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier (of the lot date code identified on the first page of this report) PASSED the SEL test with no significant events detected at the worst-case tested LET of 88MeV-cm^2/mg and at the worst-case temperature of 125°C. Further, the unit-under-test continued operating normally based on a check of the output levels without needed to cycle power. Note that SET events were detected during the course of the SEL test and are reported in a separate report (as noted above). However the SET events were short lived and the unit returned to proper operation within a short period of time.

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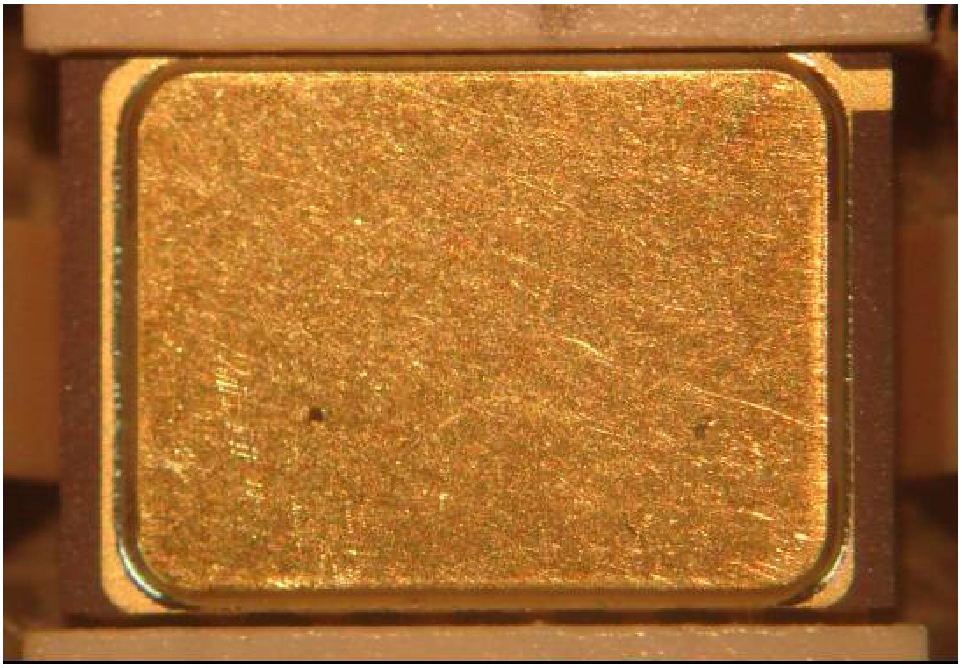
Appendix A: Photograph of a Sample Unit-Under-Test (front and reverse sides) for Device Traceability and a Decapsulated Unit Ready for SEL Testing



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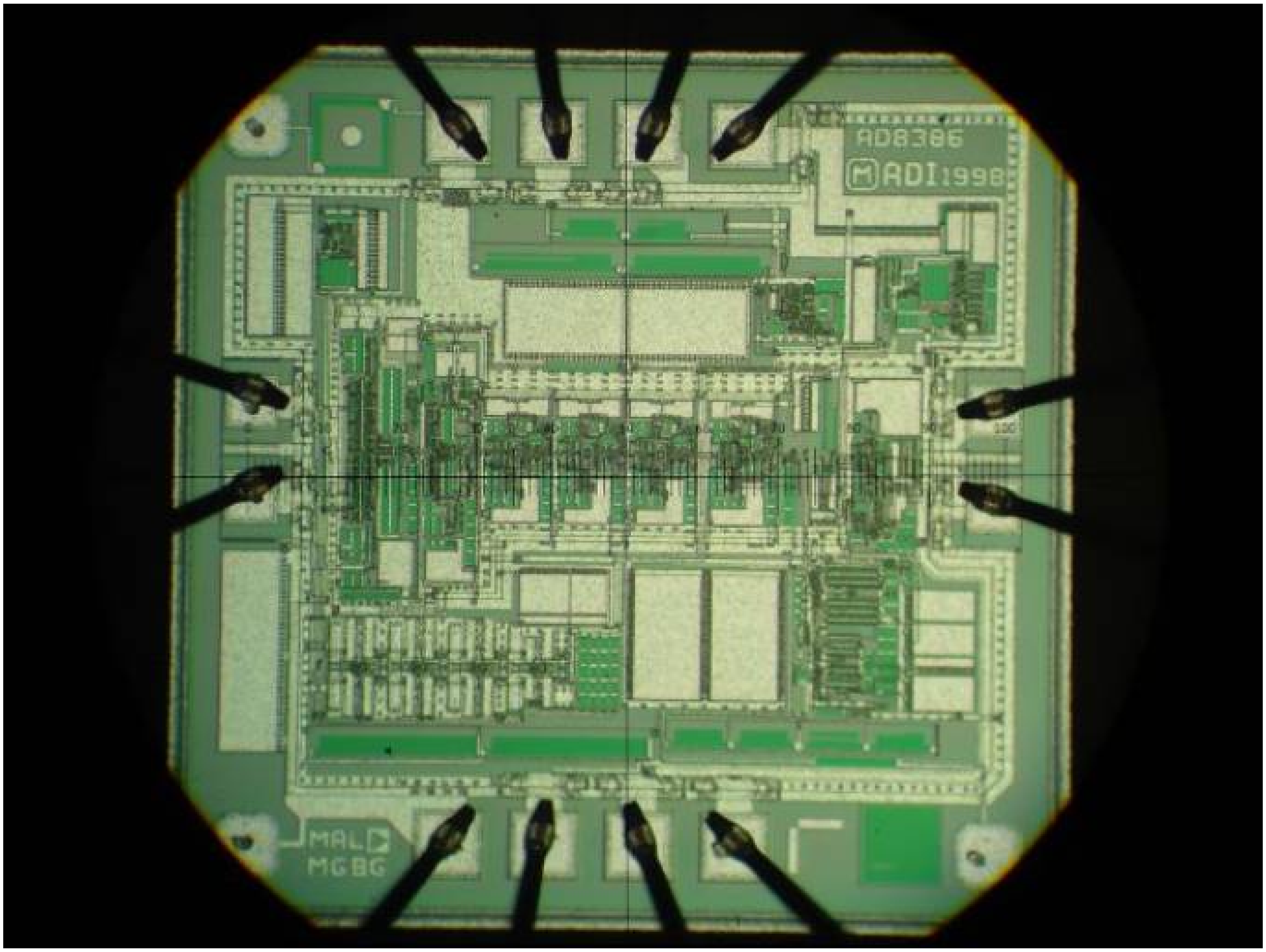

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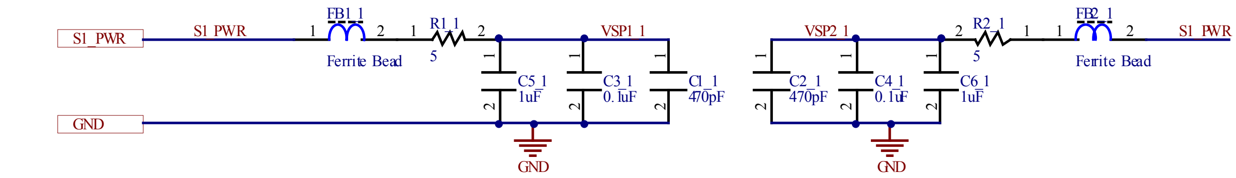
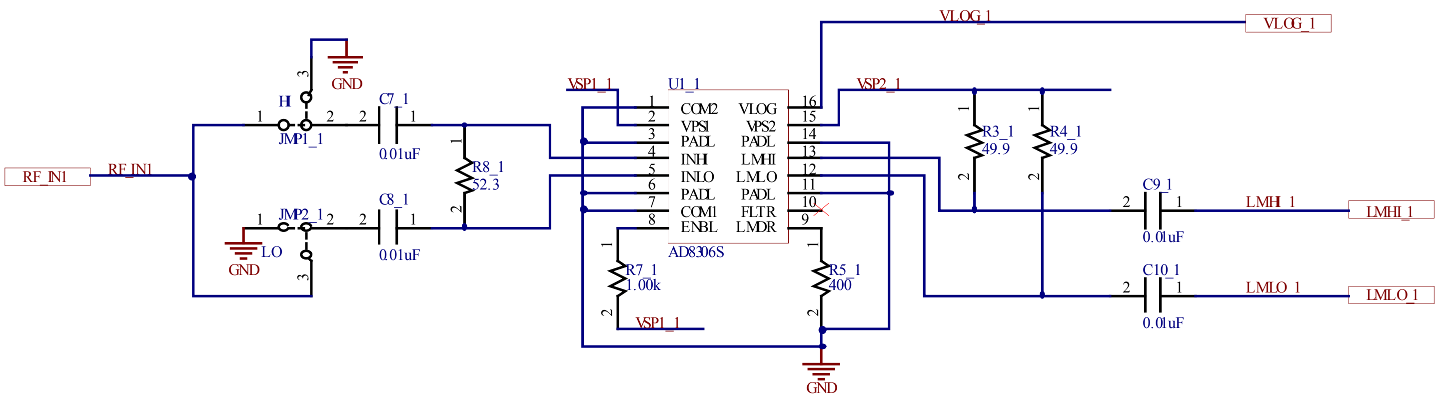
Appendix B: Schematic of and Photograph of the Test Board (Single Test Site) Used During Heavy Ion Exposure and Functional Block Diagram of the Unit-Under-Test





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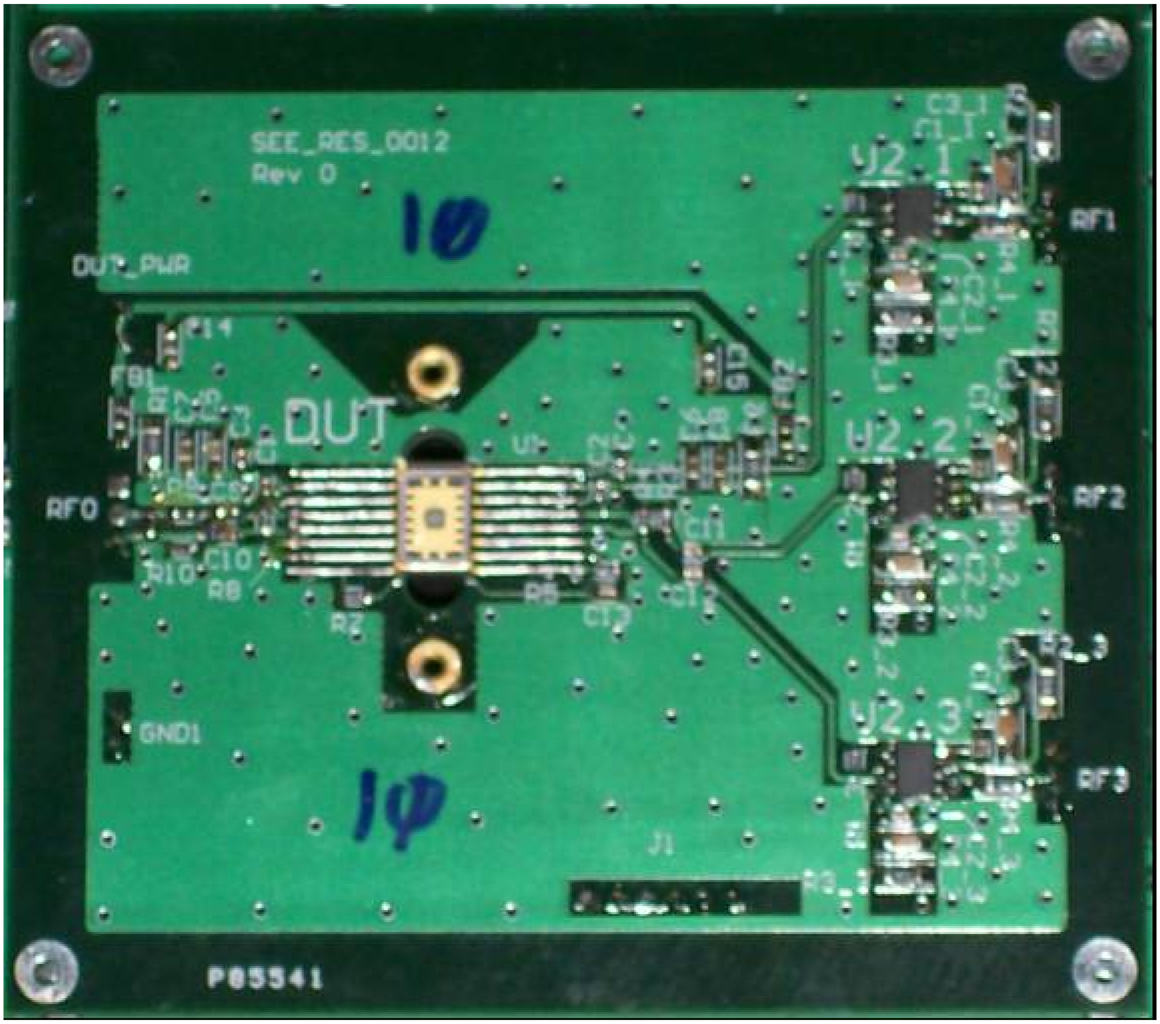

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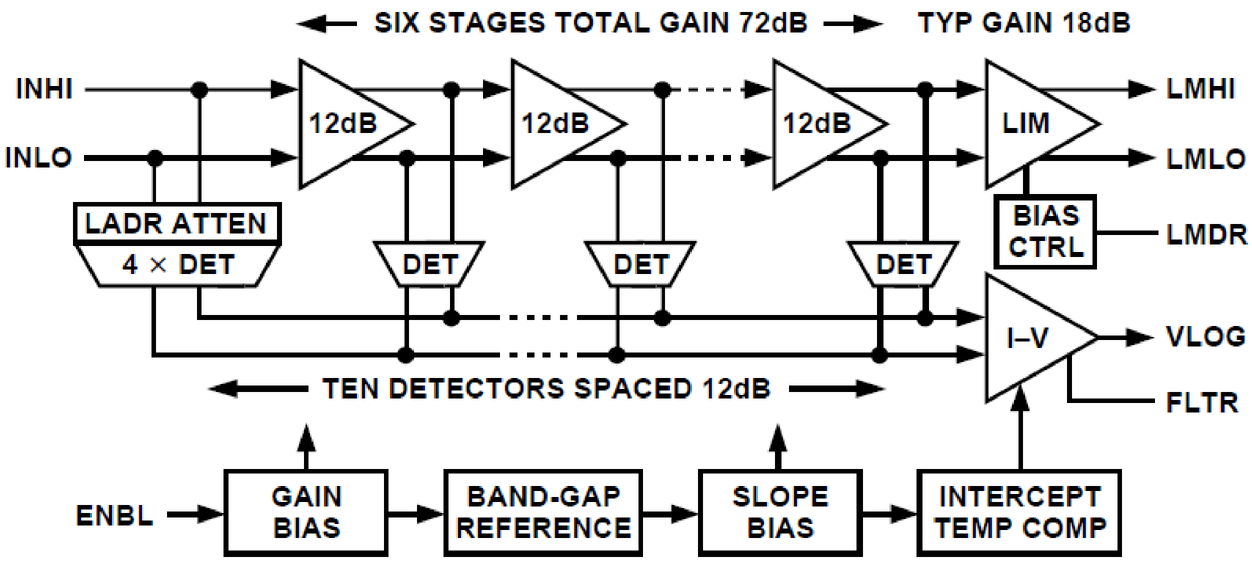
FUNCTIONAL BLOCK DIAGRAM



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Appendix C: Electrical Test Parameters and Equipment List

The single event latch-up testing described in this final report was performed at the Lawrence Berkeley National Laboratories (LBNL) using the 88-Inch Cyclotron. The 88-Inch Cyclotron is operated by the University of California for the US Department of Energy (DOE) and is a K=140 sector-focused cyclotron with both light- and heavy-ion capabilities. Protons and other light-ions are available at high intensities (10-20pμA) up to maximum energies of 55 MeV (protons), 65 MeV (deuterons), 135 MeV (3He) and 140 MeV (4He). Most heavy ions through uranium can be accelerated to maximum energies, which vary with the mass and charge state.

The devices were irradiated to a minimum fluence of 1E7ion/cm2, if no events were detected. Table C.1 shows the test equipment used for this testing.

Table C.1. Test equipment and calibration dates for testing the AD8306 5 MHz–400 MHz 100 dB High Precision Limiting-Logarithmic Amplifier

HP 34401A Multimeter	3146A65284	5/15/011	5/15/12	I_{CC} measurement
Agilent E3642A DC Power Supply	MY40004345	N/A	N/A	Test power supply-Positive Supply
Agilent E3631A DC Power Supply	K920920312	N/A	N/A	Test power supply-Negative Supply
Fluke Model 77 Multimeter	38301747	2/19/11	2/19/12	Vcc measurement at the DUT
Omega HH12 Handheld Thermometer	233126	2/19/11	2/19/12	Temperature Calibration
Tektronics TDS5104B Oscilloscope	B011044	10/22/10	10/22/11	Output Waveform Measurements