SINGLE EVENT LATCH-UP TEST REPORT

PRODUCT:	ADL5513/QMLR
DIE TYPE:	ADL5513
DATE CODE:	1132
CASE TEMPERATURE:	125°C
EFFECTIVE LET:	80.2 MeV-cm2/mg
MINIMUM FLUENCE:	1E7 ion/cm2
FLUX:	~1E5 ion/cm2-s
FACILITIES:	Texas A&M University – K500 Cyclotron Superconducting Facility
TESTED:	September 26, 2011

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ANALOG DEVICES

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Single Event Latchup Testing of the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller for Analog Devices

Customer: Analog Devices (PO# 45352065)

RAD Job Number: 11-473

Part Types Tested: Analog Devices ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller. The units were irradiated on September 26th, 2011.

Traceability Information: Manufacturing Code: E195635.1 wafer 11 and E195637.1 wafer 12; 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 fluence of 1E7ion/cm^2 at a maximum LET of approximately 80MeV-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: Aeroflex-RAD's custom GPIB data logging software, 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 15MeV/n Kr and Ho beams with a maximum effective LET of approximately 80MeV-cm^2/mg. The 15MeV/n Xe beam has a range of to the Bragg peak of approximately 1000μm in silicon (which is the shortest range particle used).

Heavy Ion Flux and Maximum Fluence Levels: Flux of approximately 1 to 2E5ions/cm2. Minimum 1E7 ions/cm^2 per unit tested when no events were detected.

Facility and Radiation Source: Texas A&M University (TAMU) using the K500 Cyclotron and the 15MeV/n beam.

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

The ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller is IMMUNE to SEL events to the maximum tested LET of approximately 80MeV-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 Texas A&M University (TAMU) using their K500 Cyclotron. The testing was performed in air using the 15MeV/n beam. This beam was selected since it provides plenty of range for de-encapsulated or delidded die being irradiated from the top surface and offers a wide selection of ions and LETs. When necessary, beam degraders can be inserted into the beam line to achieve the desired LET and a wider LET range for a given ion. The beam characteristics and dosimetry were provided by the Texas A&M heavy ion test facility. TAMU can deliver the beam with a high degree of uniformity over a 1-inch diameter circular cross sectional area using the in-air test system. Uniformity is achieved by magnetic defocusing and by thin foil scattering. The beam uniformity and flux are determined using an array of five plastic scintillators coupled to photo multiplier tubes, located in the diagnostic chamber adjacent to and upstream from the target. Four of the five detectors are fixed in position and set up to measure beam particle counting rates continuously at four characteristic points - 1.64 inches (4.71 mm) away from the beam axis center. The fifth scintillator is inserted to measure the beam particle counting rate right at the beam axis and is removed to provide an unobstructed beam during testing. The control software determines the beam uniformity (ranging from 0 to 100%), axial gain (%), and beam flux (in particles/cm^2/s) based on the scintillator counting rates. The parameters are displayed on the computer screen in the control room and are updated about once every second.

For the SEL testing described in this final report the units-under-test were placed in the exposure room and aligned with the heavy ion beam line. The test stage has full x and y alignment capabilities along with 2-dimensional rotation, allowing for a variety of effective LETs for each ion. Each ion is calibrated just prior to use using five photomultiplier tubes (PMTs), as discussed above. Figure 2.1 shows an illustration of the facility; including the location of radiation effects facility, where heavy ion SEE testing takes place.

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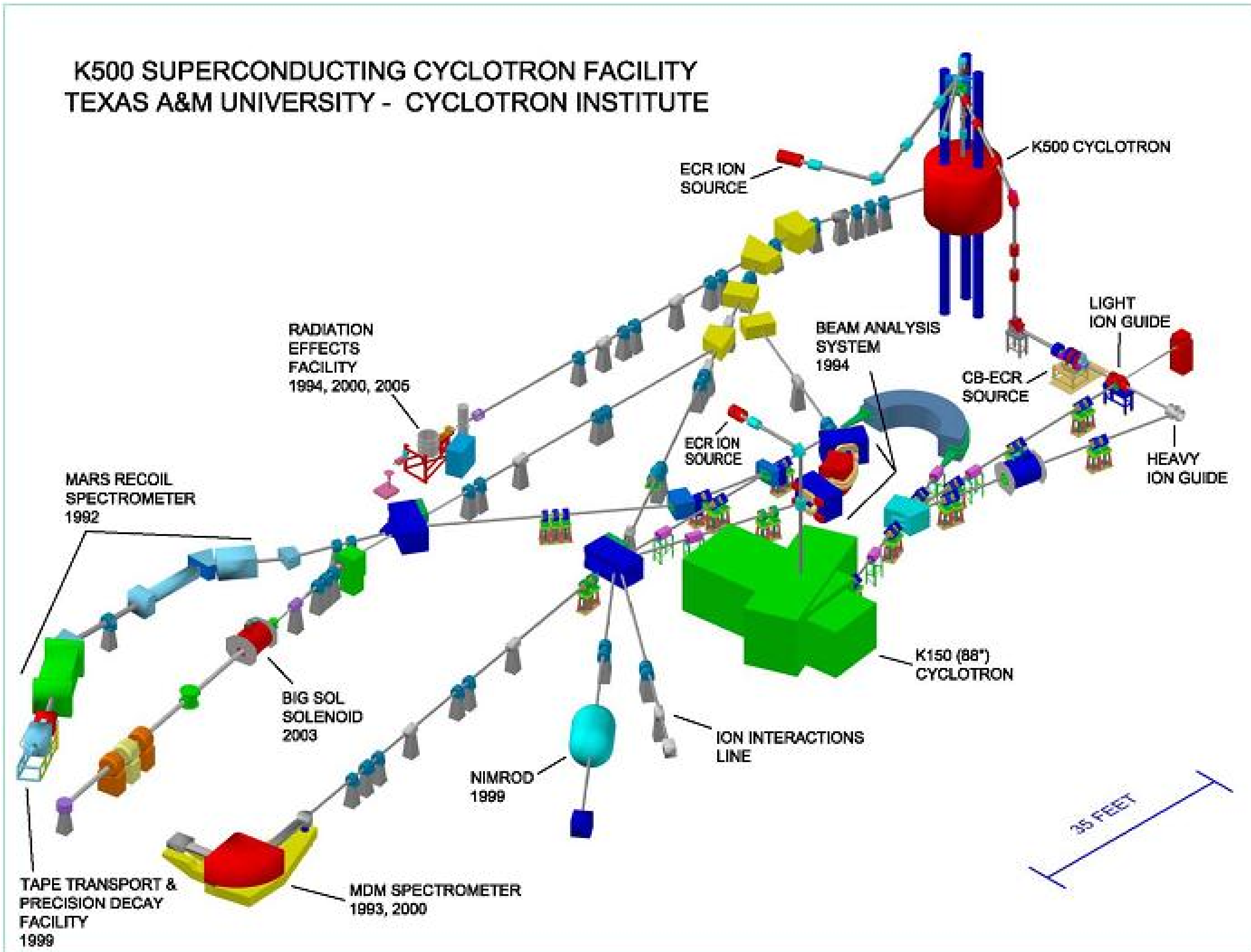

Figure 2.1. Map of K500 Cyclotron Facility at Texas A&M University. The location of the radiation effects, where the SEE testing discussed in this report was performed, is shown on the left-hand side of the diagram.

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3.0. Radiation Test Conditions

The ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller described in this final report was irradiated using the 15MeV/n Kr and Ho beams at Texas A&M University using a single sided supply voltage of +5.5V and at the worst-case temperatures of 125°C (±5°C). Figure 3.1 shows the test board (mother board and daughter card) 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 TAMU and provided 3-axis of motion plus rotation. The board had multiple units-under-test that allowed for sequential testing of the units without having to enter the exposure room 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. Outputs brought out for monitoring
3. Log Amp inputs held at steady-state cw rf signal during testing
4. V_{OUT} tied to V_{SET} (20mV/dB) on daughter card
5. T_{ADJ} set at 0.9V
6. Outputs are buffered with Gain = +2 (Ideal output at scope should range from 1.6V to 3.3V). Range is limited by input signal and system noise floor.

The 15MeV/n beam was used to provide sufficient range in silicon while meeting the LET requirements of the program. The other beams available at TAMU are the 25MeV/n beam and the 40MeV/n beam. While both the 25MeV/n and 40MeV/n beam would provide additional range for this type of SEE testing, the additional cost of using these beams is not justified since the 15MeV/n fully penetrates the active layer with a range to the Bragg peak of at least 50µm.

Figure 3.2 shows the 15MeV/n beam characteristics for holmium calculated using SRIM. As seen in the figure, the 15MeV/n Ho beam has a surface LET of approximately 67MeV-cm^2/mg, an LET of approximately 82MeV-cm^2/mg at the Bragg peak and a range to the Bragg peak of more than 100µm in silicon. Figure 3.3 shows the characteristics for all the 15MeV/n beams available at TAMU.

Note that the units-under-test were decapsulated prior to testing and all exposures took place from the top surface in air and through an Aramica foil. Based on the technology of the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller we assume a distance to the active layer in silicon of approximately 5 to 10µm.providing for an LET to the unit-under-test of approximately 80MeV-cm^2/mg. See Appendix A for a photo of the die (unit-under-test delidded in preparation for the SEE testing).

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During the irradiation, the flux varied somewhat, 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 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 or ribbon cable.

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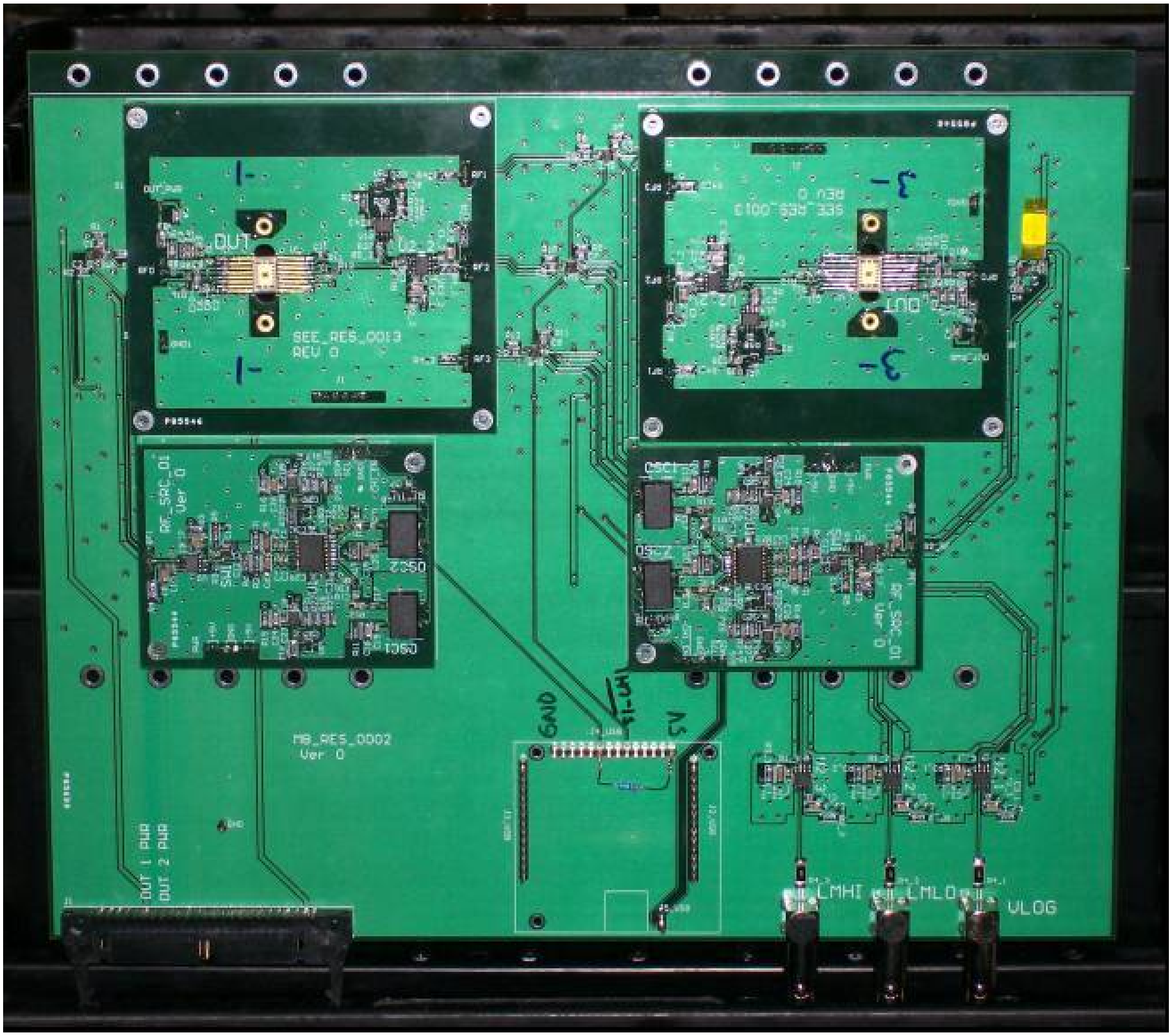

Figure 3.1. Single event test board prepared for mounting on the test stage at TAMU. The board has two units-under-test mounted simultaneously to minimize interruptions during testing. There is also a heater plate mounted to the backside of the daughter cards to provide the elevated temperature required for this testing. Also seen on the motherboard are two custom RF source daughter cards used to supply clean 5MHz or 10MHz signals to the units-under-test.

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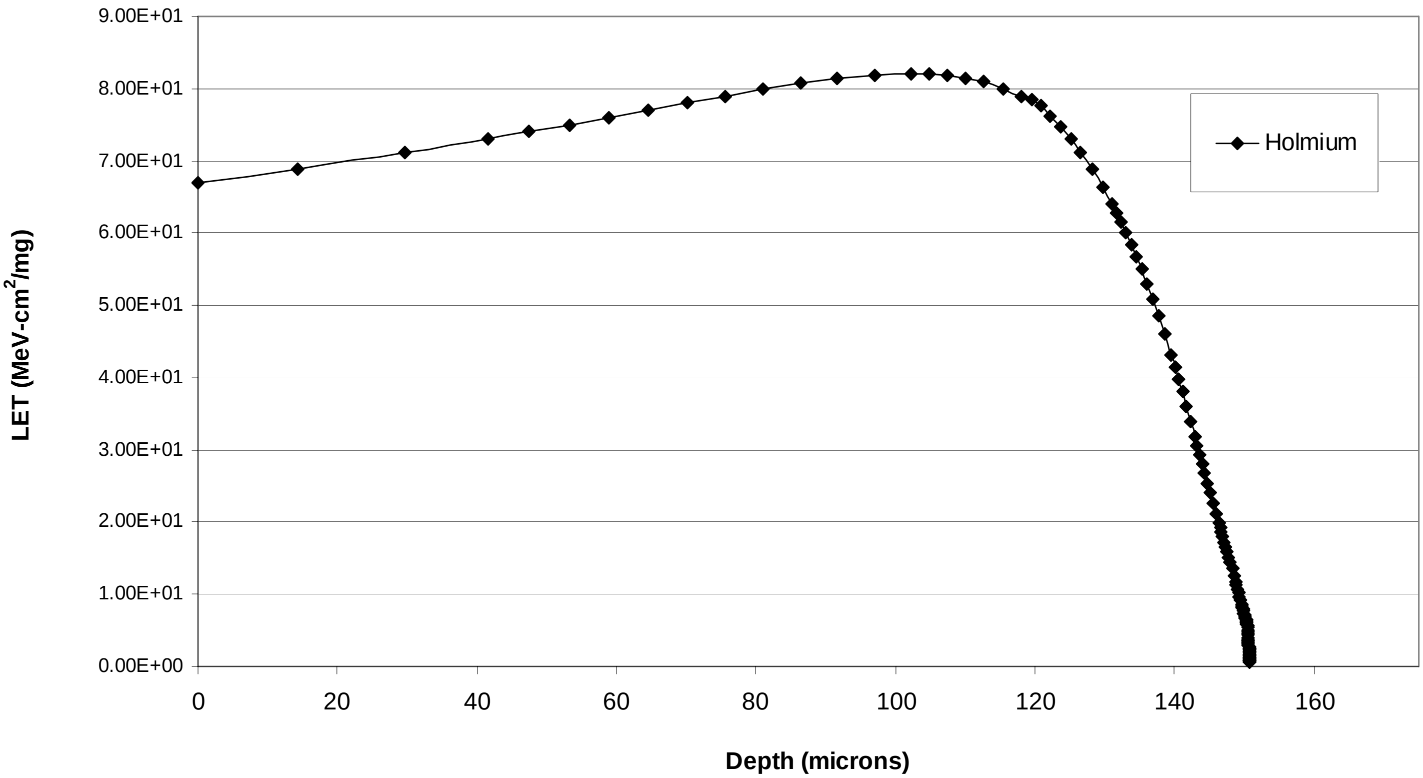

Figure 3.2. Range of the 15MeV/n Ho beam into silicon. The range to the Bragg Peak for Holmium (the shortest range ion used) is approximately 100µm while the surface LET is approximately 67MeV-cm^2/mg. The LET at the Bragg peak rises to over 80MeV-cm^2/mg.

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	Ion	Mass (amu)	A MeV	Total Energy (MeV)	Range in Si (μm)	Range to Bragg Peak (μm)	Initial LET	LET at Bragg Peak
15 A MeV	^{20}Ne	19.992440	15	300	316	309	2.5	9.6
	^{40}Ar	39.962383	15	599	229	220	7.7	20.1
	^{63}Cu	62.929601	15	944	172	157	17.8	34.0
	^{84}Kr	83.911507	15	1259	170	149	25.4	41.4
	^{109}Ag	108.904756	15	1634	156	130	38.5	54.8
	^{129}Xe	128.904778	15	1934	156	125	47.3	63.4
	^{141}Pr	140.907648	15	2114	154	117	53.8	69.6
	^{165}Ho	164.930319	15	2475	156	112	64.3	79.2
	^{181}Ta	180.947996	15	2715	155	107	72.2	86.4
	^{197}Au	196.966552	15	2955	155	102	80.2	93.5

Figure 3.3. Characteristics of all the 15MeV/n beams available at Texas A&M University. For the testing discussed in this report the 15MeV/n beam was used exclusively.

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4.0. Tested Parameters

During heavy ion exposure the positive supply current to the units-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 Latchup Test Results").

During the heavy ion exposure the output of the units-under-test (V_{OUT}, see the functional block diagram of the unit-under-test in Appendix B) were measured for proper operation/output signal. The units were run dynamically with a 5MHz signal on the clock (supplied by a custom RF source daughter card) with the output captured on a digitizing oscilloscope. Note that the output transients are reported separately in a report entitled "Single Event Transient Testing of the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller for Analog Devices". However, for the SEL portion of the testing discussed in this final report 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_{OUT} pin.

Table 4.1 summarizes the single event transient tests performed for the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller. 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 power (DUT power = +5.5V, board power = ±5V)
2. Select Site 1 by setting (1 state) S1_EN
3. Select RF input Frequency of 5MHz (S1_CH1_EN = 0)
4. Program RF Source for maximum output (send 0xFF in both bytes)
5. Observe VOUT output (J4) using scope or multimeter
6. Adjust temperature to +125°C
7. Turn ON ion beam, observe/monitor/log device current
8. 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 ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller.

DUT	Wafer	Temp	Ion	Nominal Range (um)	Effective LET (MeV-cm2/mg)	Effective Range (um)	Effective Fluence (ion/cm2)	Dose (rad)	Average Flux (ions/cm2/s)	Angle	Degrader
2	11	125	Kr	39.1	55.0	27.7	1.00E+07	8.83E+03	1.05E+05	45	2,45
4	12	125	Ho	48.7	80.2	48	2.04E+06	2.63E+03	1.26E+05	10	1,59
4	12	125	Ho	48.7	80.2	48	9.98E+06	1.28E+04	1.27E+05	10	1,59
3	11	125	Ho	48.7	80.2	48	9.98E+06	1.28E+04	7.58E+04	10	1,59

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5.0. Single Event Latch-Up Test Results

The ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller (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 80MeV-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).

Table 5.1 show a summary of the single event latch-up data acquired and the results. The table shows the part type (ADL5513), the serial number of the part irradiated, the test configuration (all units irradiated with a 5MHz clock and static data inputs), 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 15krad(Si) of total ionizing dose (TID) during any run and, therefore and in our opinion TID damage did not play a significant role in these results.

Figures 5.1 through 5.3 show the supply current data during the SEL runs. In these figures the supply currents (positive and negative 5.25V power supplies) are plotted as a function of time. The plots show the response of the unit-under-test from the start heating to the end of heavy ion exposure (See Table 4.1 or 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.

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Table 5.1. Summary of the SEL test runs for the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller.

DUT	Wafer	Temp	Ion	Effective LET (MeV-cm2/mg)	Effective Range (um)	Effective Fluence (ion/cm2)	Angle	SEL Events
2	11	125	Kr	55.0	27.7	1.00E+07	45	None
4	12	125	Ho	80.2	48	2.04E+06	10	None
4	12	125	Ho	80.2	48	9.98E+06	10	None
3	11	125	Ho	80.2	48	9.98E+06	10	None

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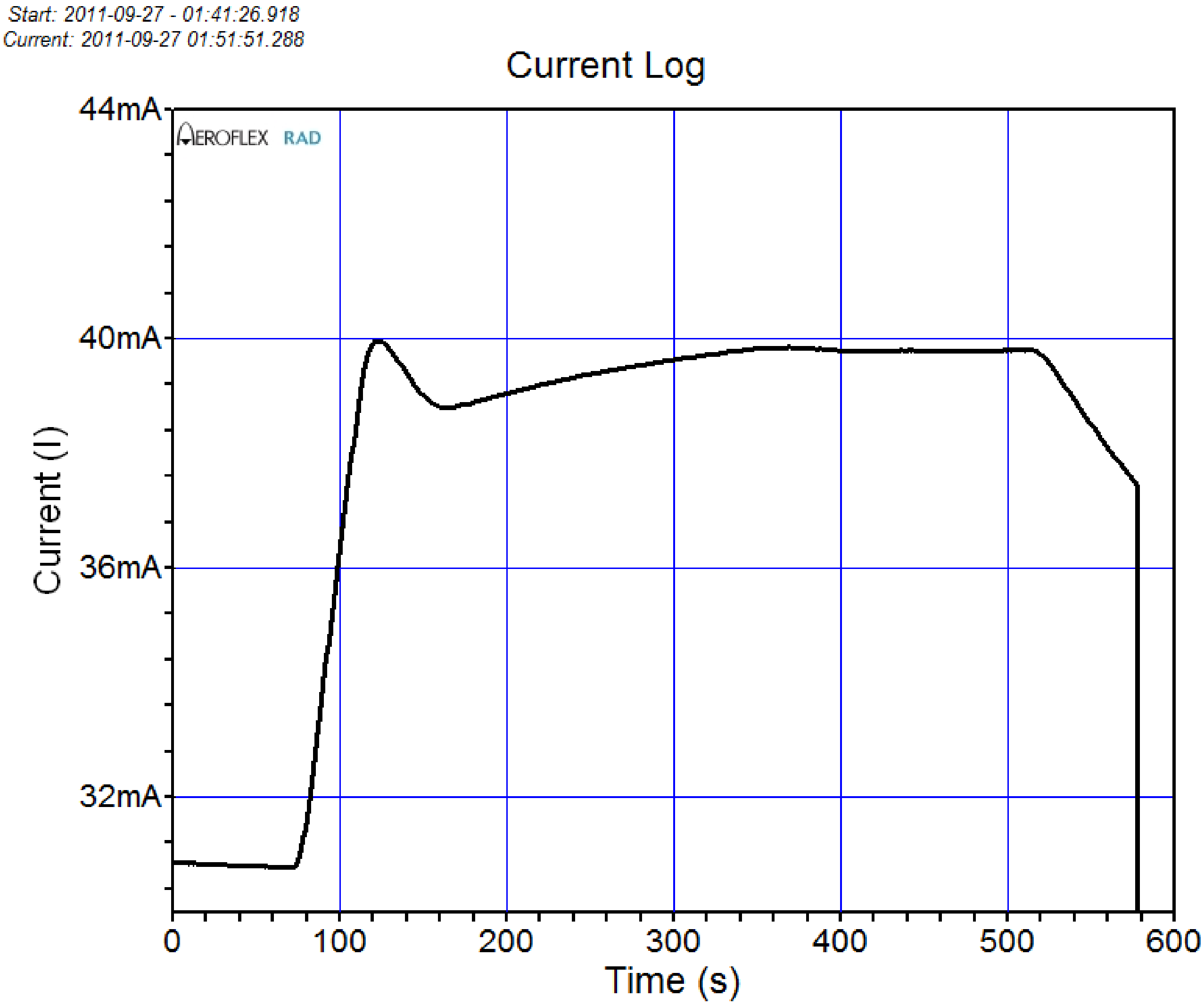

Figure 5.1. Input supply current versus time/fluence for the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller (run 39). See Table 4.1 for the details of the test conditions. This figure shows the increase in current during heating of the unit-under-test to 125°C (approximately 0 to 400s) and the current during the beam run (approximately 400s to 500s). As seen in this plot, the unit-under-test is not susceptible to single event latchup events.

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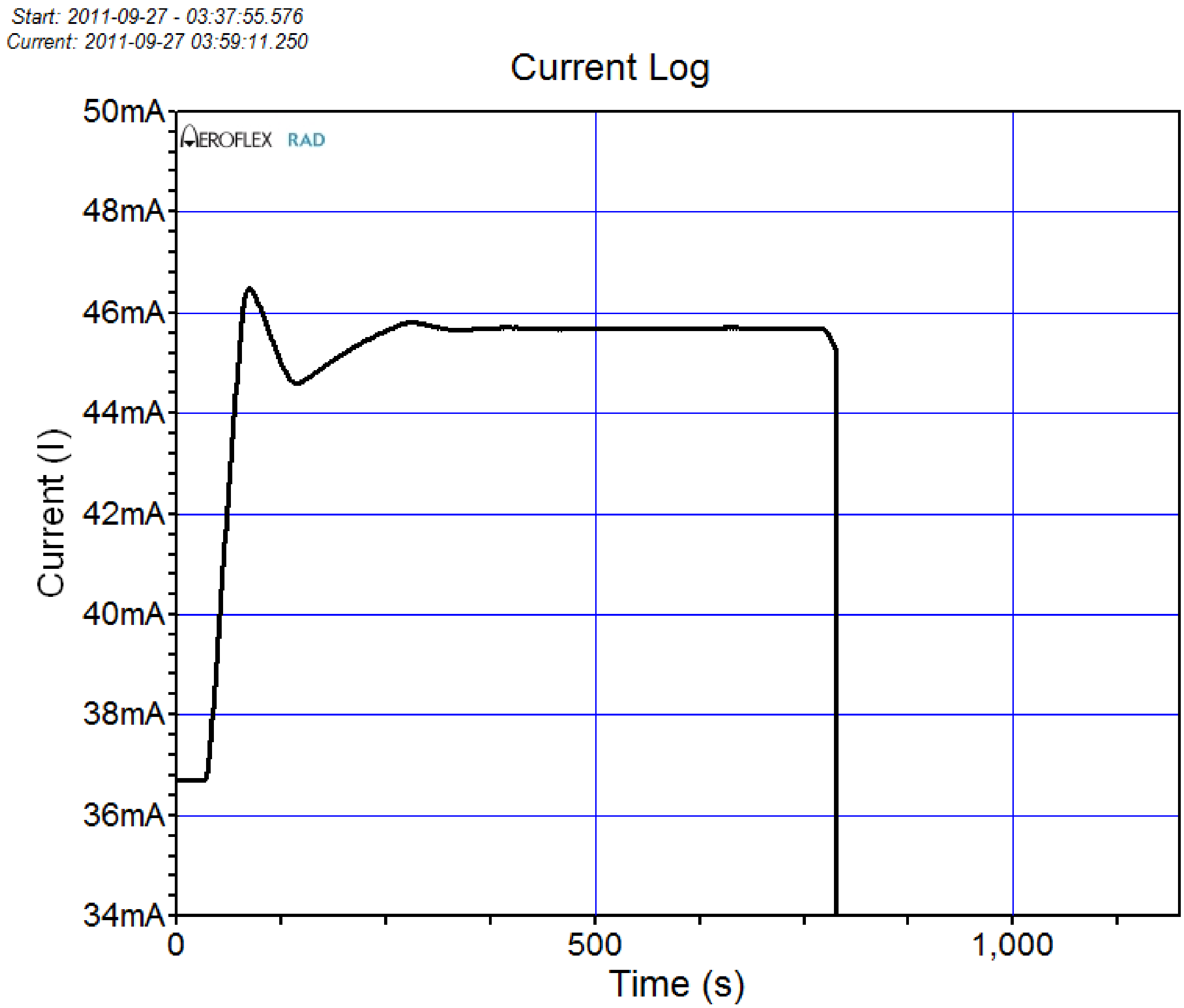

Figure 5.2. Input supply current versus time/fluence for the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller (run 47). See Table 4.1 for the details of the test conditions. This figure shows the increase in current during heating of the unit-under-test to 125°C (approximately 0 to 400s) and the current during the beam run (approximately 400s to 500s). As seen in this plot, the unit-under-test is not susceptible to single event latchup events.

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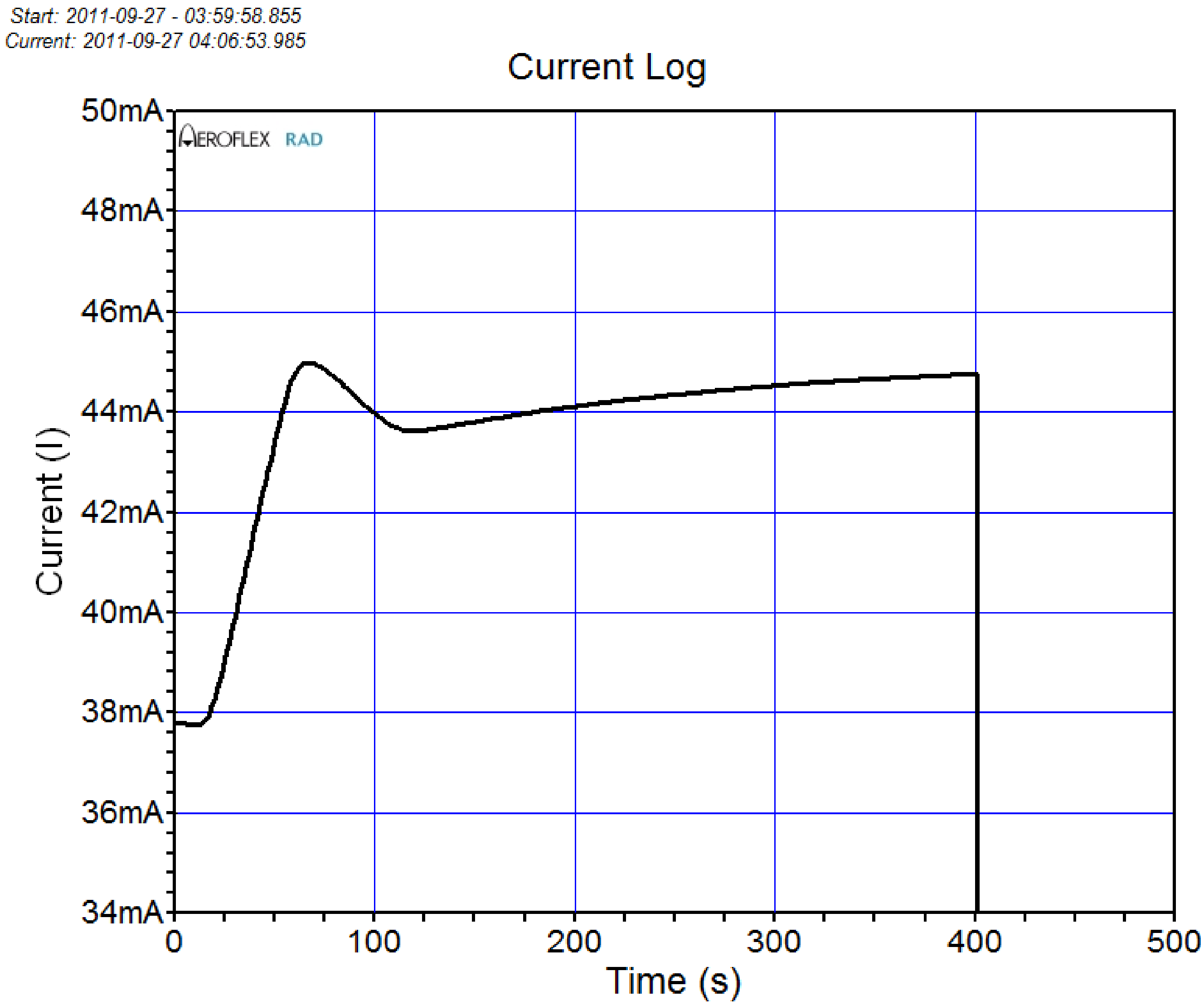

Figure 5.3. Input supply current versus time/fluence for the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller (run 48). See Table 4.1 for the details of the test conditions. This figure shows the increase in current during heating of the unit-under-test to 125°C (approximately 0 to 300s) and the current during the beam run (approximately 300s to 400s). As seen in this plot, the unit-under-test is not susceptible to single event latchup events.

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6.0. Summary/Conclusions

The single event latch-up testing described in this final report was performed at Texas A&M University (TAMU) using the K500 Cyclotron. The testing was performed in air using the 15MeV/n beam. This beam was selected since it provides plenty of range for de-encapsulated or delidded die being irradiated from the top surface and offers a wide selection of ions and LETs. The beam characteristics and dosimetry were provided by the Texas A&M heavy ion test facility. TAMU can deliver the beam with a high degree of uniformity over a 1-inch diameter circular cross sectional area using the in-air test system. Uniformity is achieved by magnetic defocusing and by thin foil scattering. The beam uniformity and flux are determined using an array of five plastic scintillators coupled to photo multiplier tubes, located in the diagnostic chamber adjacent to and upstream from the target.

The ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller described in this final report was irradiated using the 15MeV/n Kr and Ho beams using a single sided supply voltage of +5.5V and at the worst-case temperature of 125°C (±5°C). The test board was mounted on the test stage at TAMU and provided 3-axis of motion plus rotation. The board had multiple units-under-test that allowed for sequential testing of the units without having to enter the exposure room during testing. The devices were irradiated to a minimum fluence of 1E7ion/cm^2, if no events were detected. 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 ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller (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 80MeV-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.

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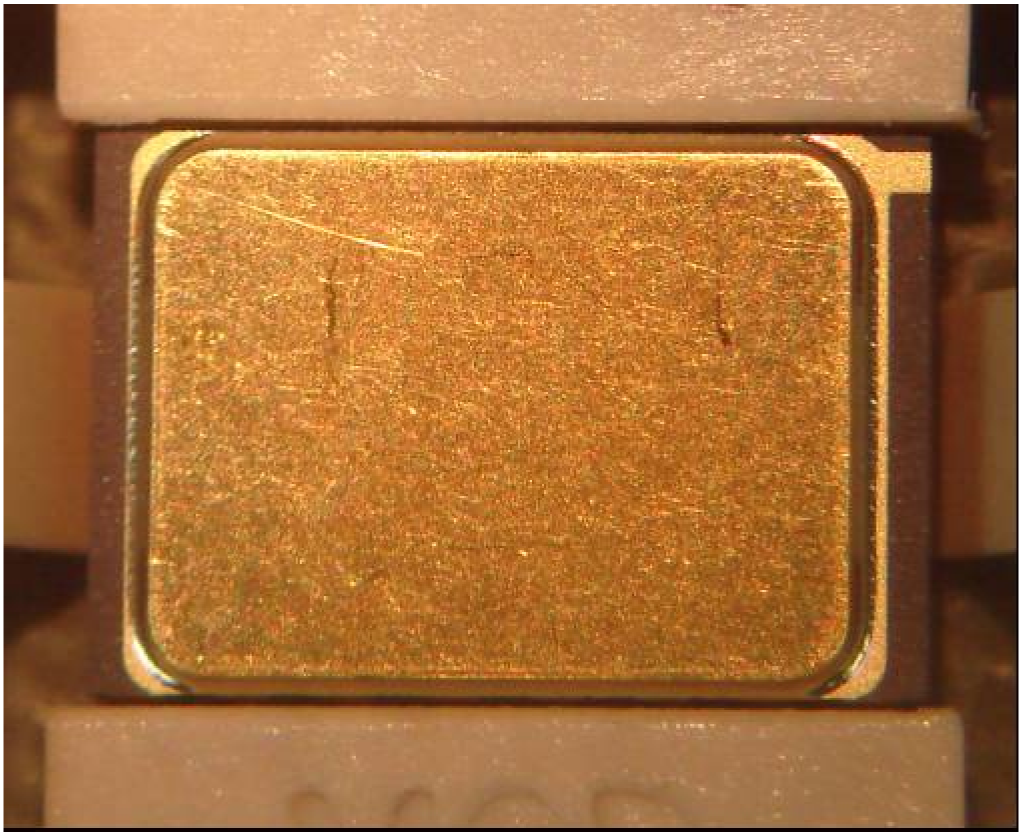
Appendix A: Photograph of a Sample Unit-Under-Test (front side, unmarked and shipping tube) for Device Traceability and a Decapsulated Unit Ready for SEL Testing



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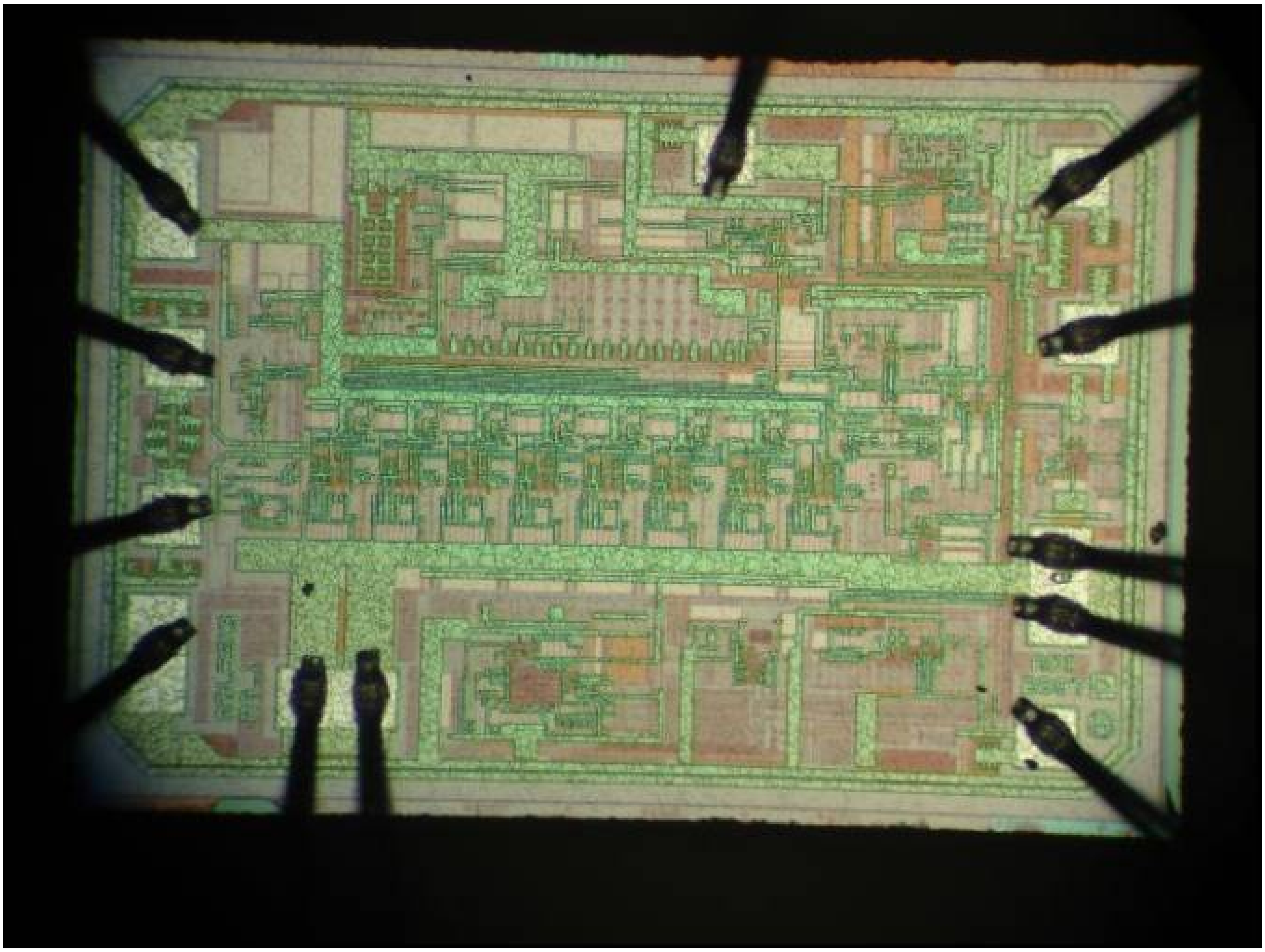

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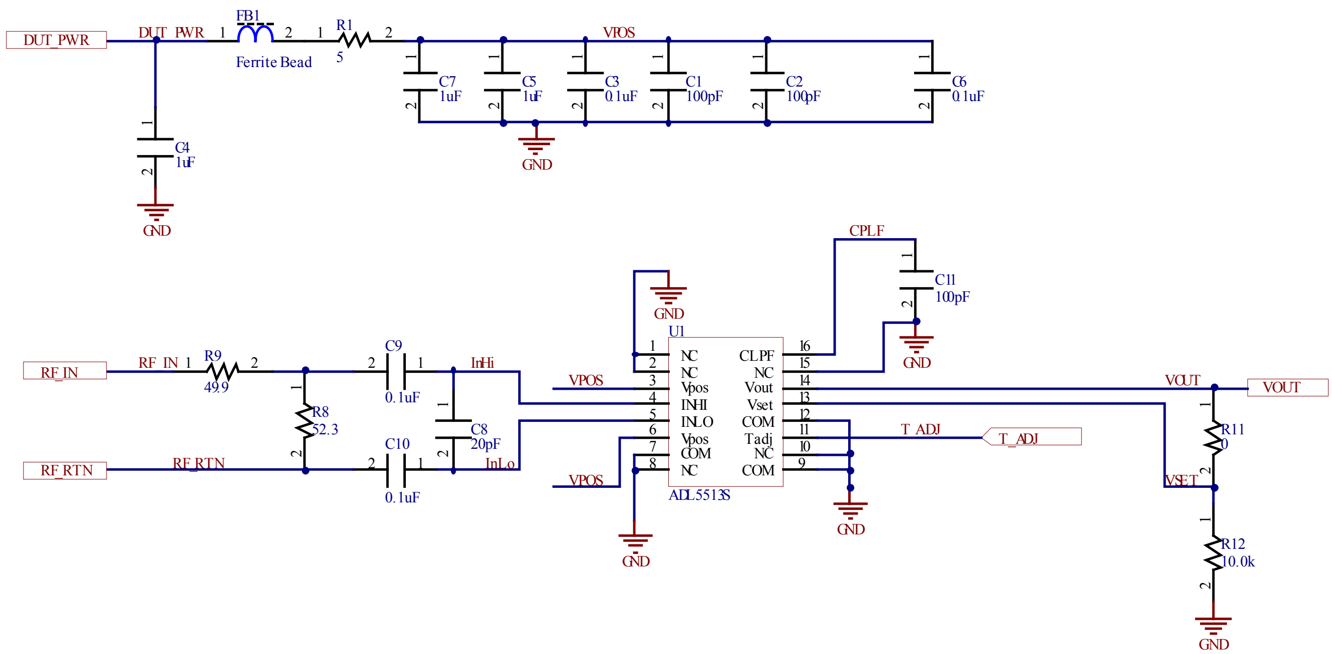
Appendix B: Schematic of Test Board (Single Test Site) and Photograph of Daughter card Used During Heavy Ion Exposure and Functional Block Diagram of the Unit-Under-Test



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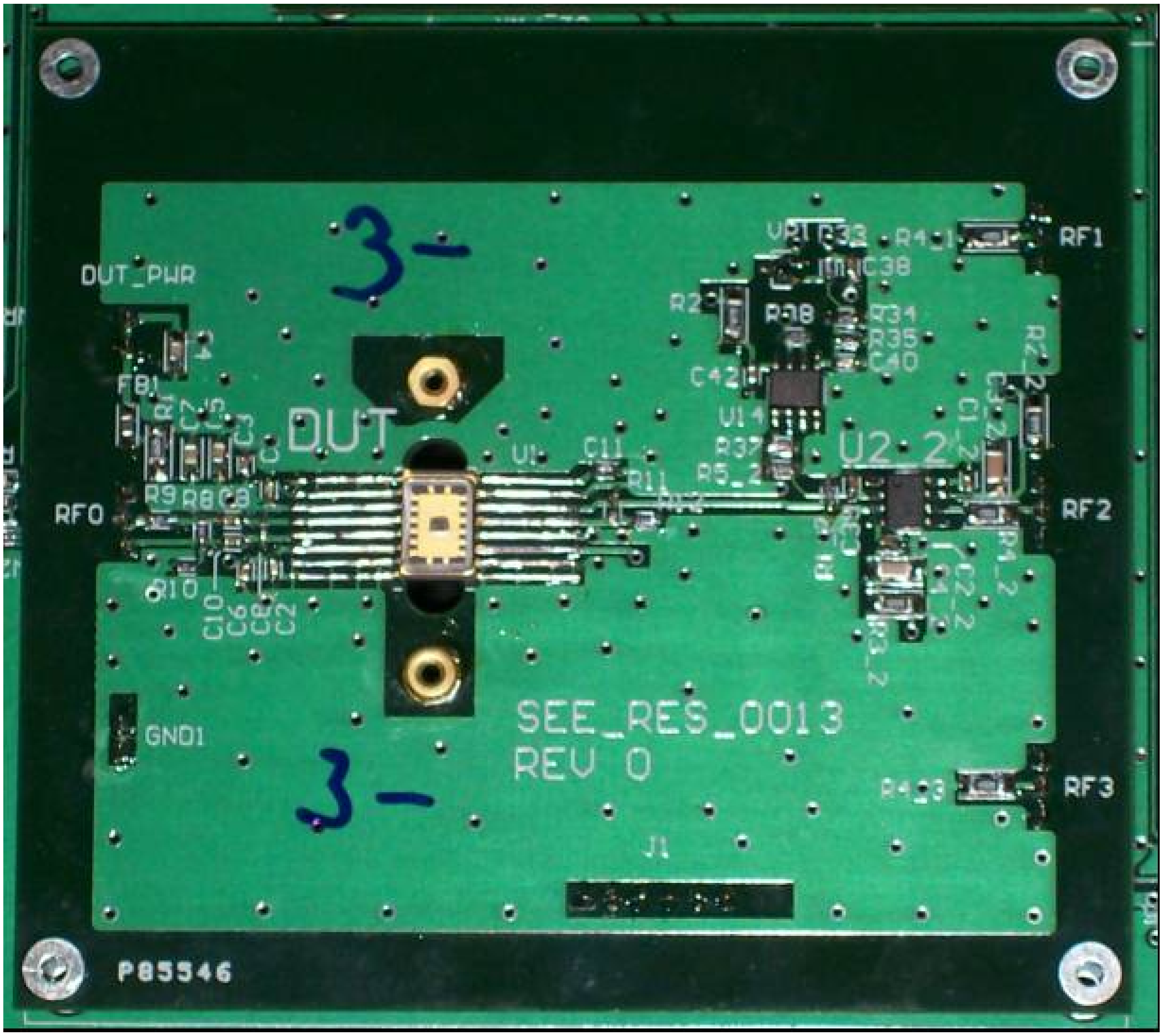

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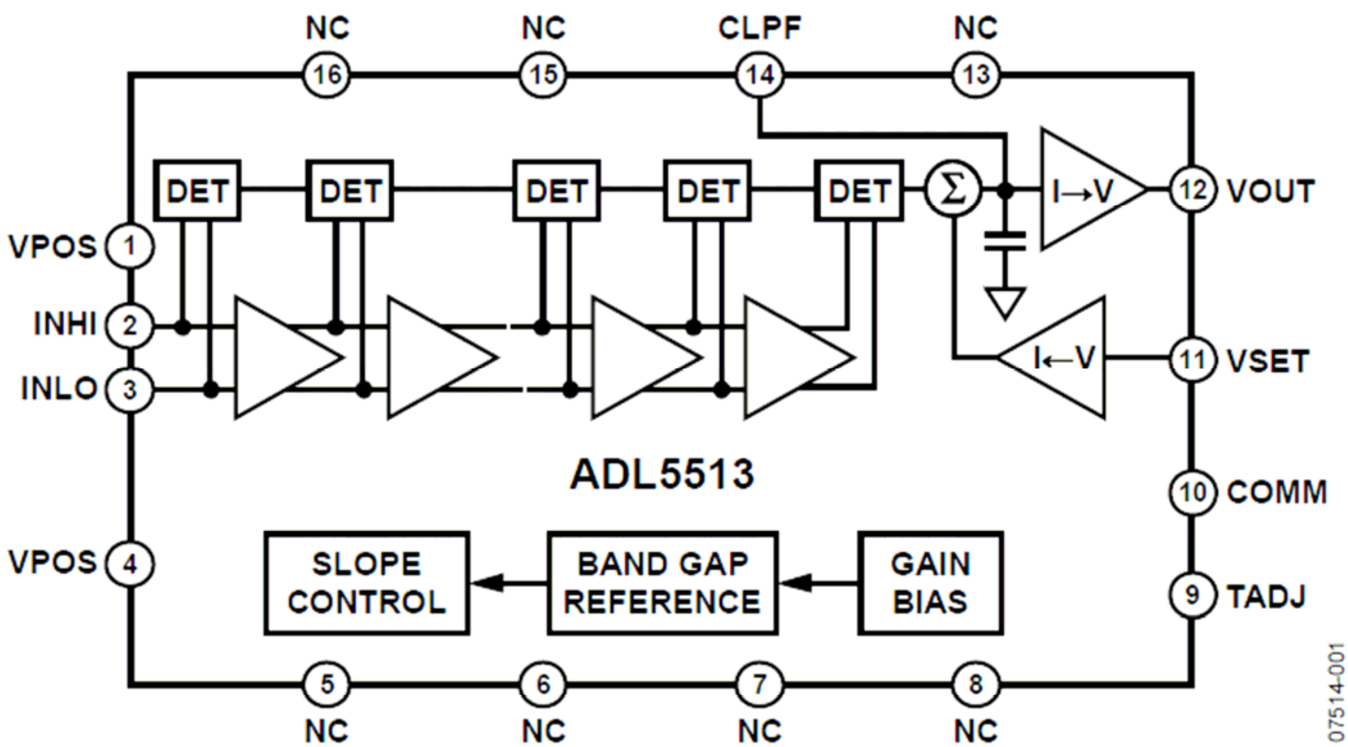
FUNCTIONAL BLOCK DIAGRAM



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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 Texas A&M University (TAMU) using the K500 Cyclotron. The testing was performed in air using the 15MeV/n beam. This beam was selected since it provides plenty of range for de-encapsulated or delidded die being irradiated from the top surface and offers a wide selection of ions and LETs. The beam characteristics and dosimetry were provided by the Texas A&M heavy ion test facility. TAMU can deliver the beam with a high degree of uniformity over a 1-inch diameter circular cross sectional area using the in-air test system. Uniformity is achieved by magnetic defocusing and by thin foil scattering. The beam uniformity and flux are determined using an array of five plastic scintillators coupled to photo multiplier tubes, located in the diagnostic chamber adjacent to and upstream from the target.

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

Table C.1. Test equipment and calibration dates for testing the ADL5513 1 MHz to 4 GHz, 80dB Logarithmic Detector/Controller

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