ANALOG DEVICES

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SINGLE EVENT LATCH-UP TEST REPORT AD8629S

August 2011

Radiation Test Report	
Product:	AD8629S
Effective LET:	9.74 - 58.8 MeV-cm^2/mg
Fluence:	1E7 Ions/cm^2
Die Type:	6498X
Facilities:	Lawrence Berkeley National Laboratories
Tested:	August 2011

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SINGLE EVENT LATCH-UP TEST REPORT

PRODUCT:	AD8629D703L
DIE TYPE:	6498X
DATE CODE:	1032
CASE TEMPERATURE:	125°C
EFFECTIVE LET:	(9.74-58.78) MeV-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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Single Event Latchup Testing of the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier for Analog Devices

Customer: Analog Devices (PO# 45352065)

RAD Job Number: 11-438

Part Types Tested: Analog Devices AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier

Traceability Information: Lot Date Code: 1032A; see a photograph of a sample unit-under-test in Appendix A for traceability information/part markings.

Quantity of Parts for Testing: Four units were exposed to a maximum fluence of 1E7ion/cm^2 at a maximum LET of approximately 80MeV-cm^2/mg using worst-case bias and at three different temperatures.

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, Kr, Cu and Ar beams with a maximum effective LET of approximately 80MeV-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 1 to 2E5ions/cm2. 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) or Texas A&M (15MeV/n beam).

Irradiation Temperature: Maximum 125°C case temperature as specified as the worst-case condition by the customer. Additional case temperatures were used to investigate the SEL behavior.

The AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier is susceptible to SEL events at various LETs and as a function of case temperature. None of the events were destructive (i.e. all units passed gross functionality following a power cycle), when using a current limit of 200mA and removing power within 10s from the beginning of the event.

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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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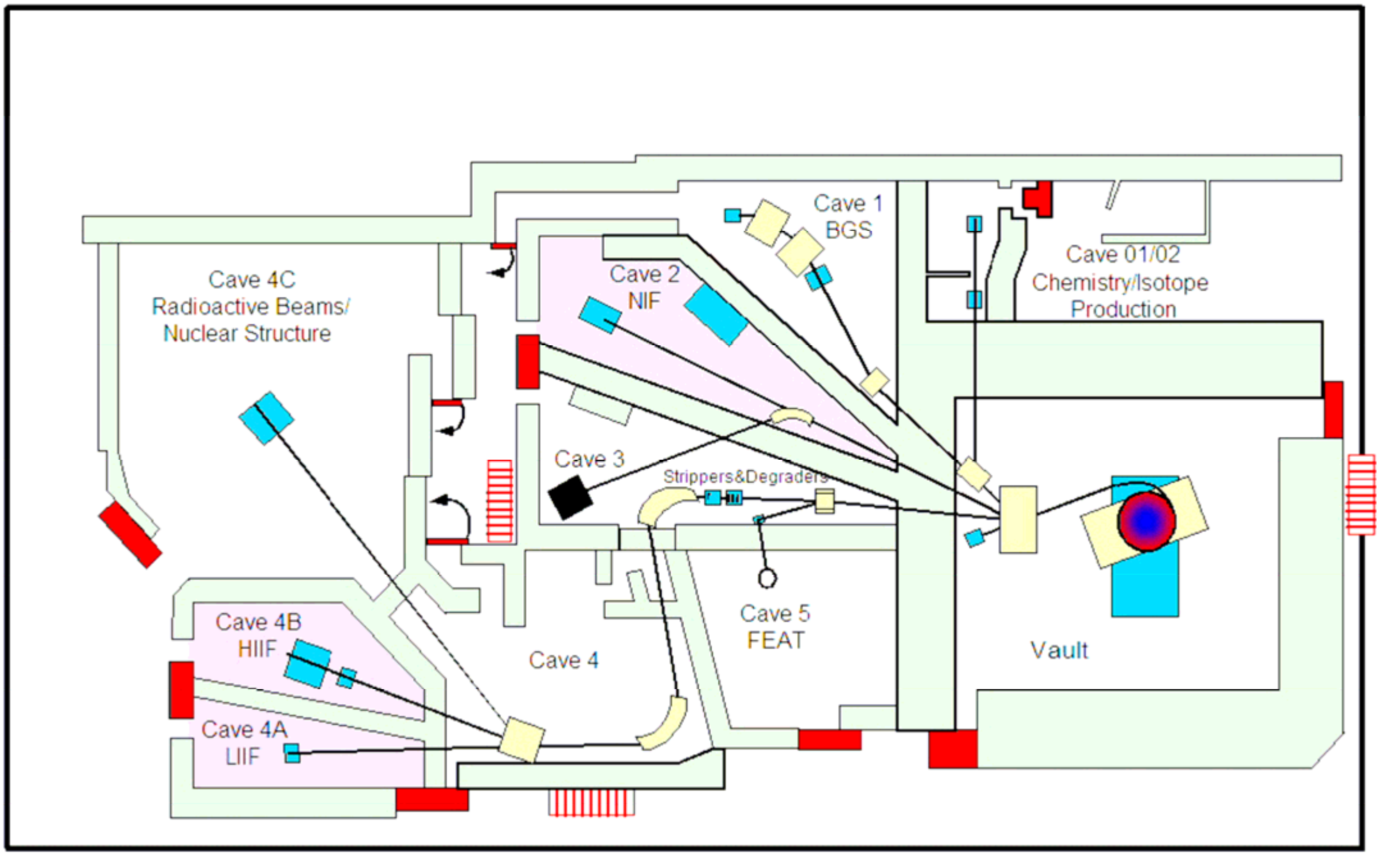

Figure 2.1. Map of 88-Inch Cyclotron Facility showing the location of Cave 4B, where the SEE testing was performed.

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3.0. Radiation Test Conditions

The AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier described in this final report was irradiated using the 10MeV/n Xe, Kr, Cu and Ar using a single ended supply voltage of 5V and at three case temperatures of 125°C, 85°C and 25°C (±5°C). Figure 3.1 shows the test board used for the SEL testing described in this final report. The test board was mounted on the test stage at Berkeley and 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. See the test circuit schematic in Appendix B for the specific details of the bias conditions.

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 1E4ion/cm^2-s. to 4E5ion/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.

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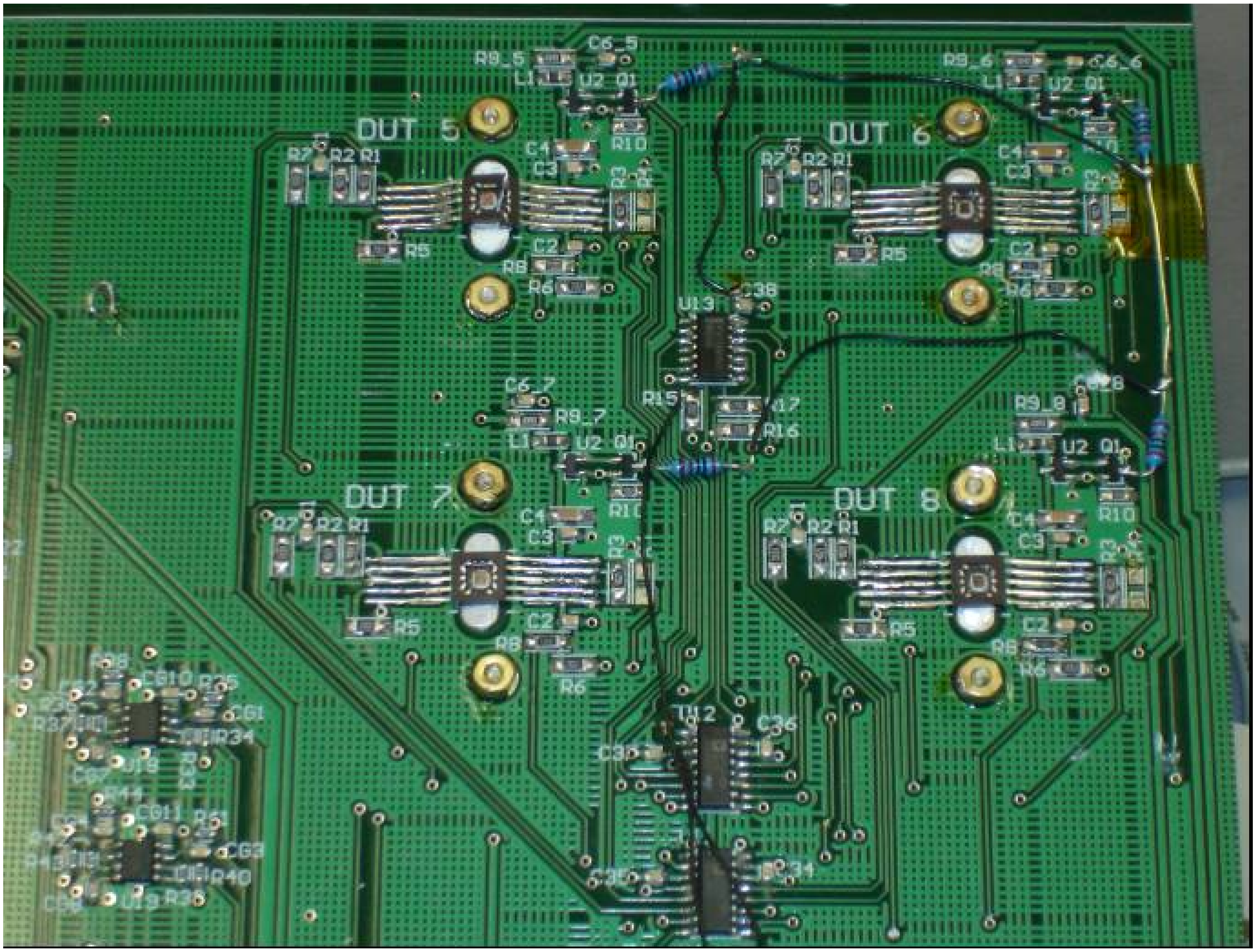

Figure 3.1. Single event test board that was mounted on the test stage at Berkeley. The board has four units-under-test (labeled as DUTs 5, 6, 7 and 8) mounted simultaneously to minimize vacuum breaks during testing. There is also a heater plate mounted to the backside of the board to provide the elevated temperature required for this testing.

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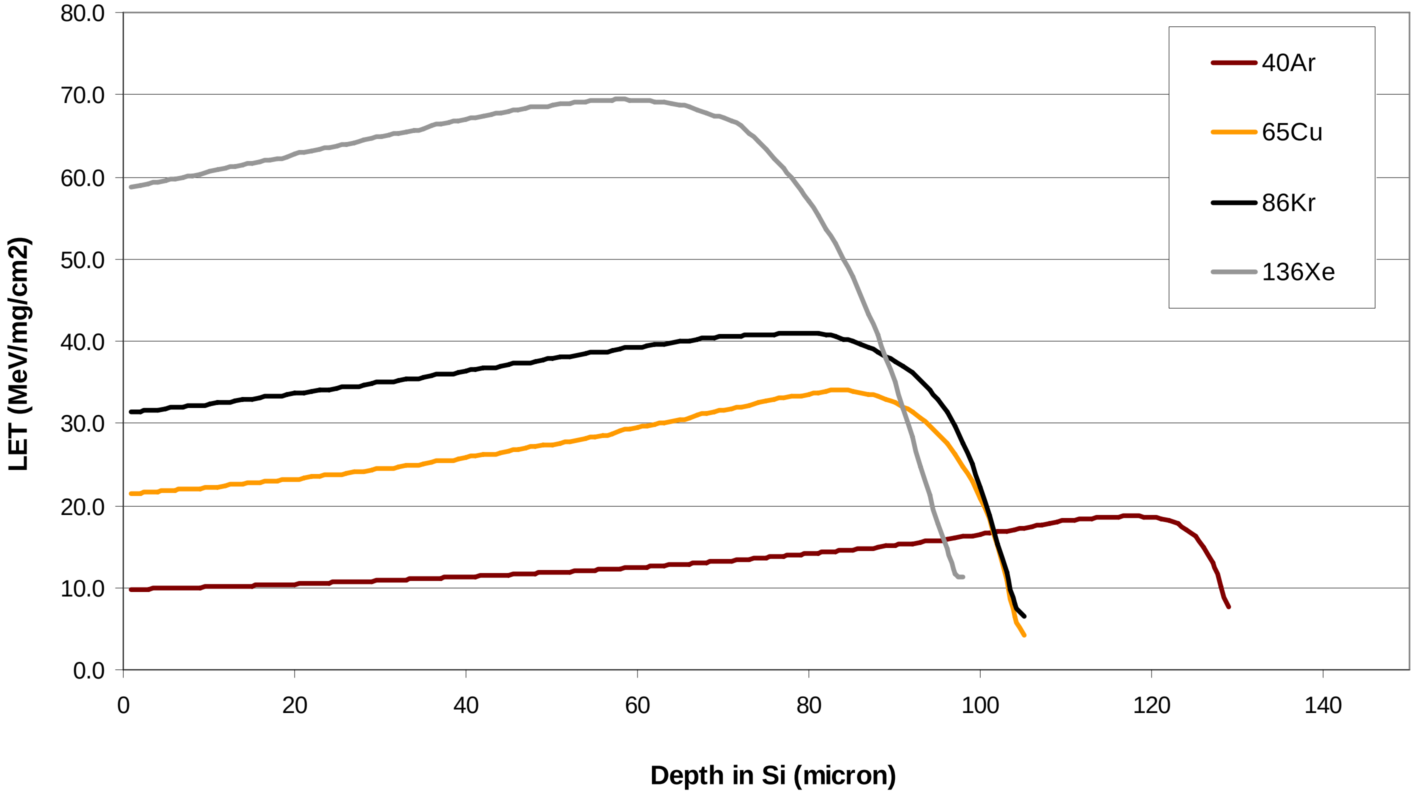

Figure 3.1. Range of the 10MeV/n Xe, Kr, Cu and Ar beams into silicon. The range to the Bragg Peak for Xe (the shortest range ion used) is approximately 60µm while the surface LET is approximately 58MeV-cm2/mg.

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Ion	Cocktail (MeV/nuc)	Energy (MeV)	Z	A	Chg. State	% Nat. Abund.	LET 0° (MeV/(mg/cm²))	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 3.2. 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 the heavy ion exposure, the supply current to the unit-under-test was measured and recorded in approximately 1-second increments. A plot of supply current 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").

During the heavy ion exposure the two outputs of the units-under-test (one configured as inverting and one configured as non-inverting) were measured for proper operation/output voltage. The units were run statically and each output was captured on a digitizing oscilloscope. Note that the output transients are reported separately in a report entitled "Single Event Transient Testing of the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier for Analog Devices". However, 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 output voltage.

Table 4.1 summarizes the single event transient tests performed for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational 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 25°C, 85°C and 125°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 (+5.00V)
2. Set "worst case" stimuli values (-2V to inverting; +2V to non-inverting) at board input (Note input stimuli range limited by buffer amplifiers, which have a gain of +2)
3. Verify correct Op Amp output voltages
4. Adjust temperature to a maximum +125°C
5. Turn ON ion beam, observe/monitor/log device current
6. Repeat process with different ions, LETs and/or case temperatures as the device response dictates.

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Table 4.1. Summary of the single event latch-up test runs for the Analog Devices AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier.

Run#	DUT	Temp (degC)	Time	Total Eff Fluence	Average Flux	Ion	Eff LET	Angle
80	AD8629 dut8 sn12	25	8/31/2011 10:03	3.16E+05	4.38E+04	Xe 58.78	58.78	0
83	AD8629 dut6 sn3	25	8/31/2011 10:15	1.02E+06	3.46E+04	Kr 30.86	30.86	0
84	AD8629 dut5 sn2	25	8/31/2011 10:28	1.02E+07	1.54E+05	Kr 30.86	30.86	0
85	AD8629 dut5 sn2	90	8/31/2011 10:32	3.04E+06	3.10E+05	Kr 30.86	30.86	0
86	AD8629 dut5 sn2	85	8/31/2011 10:44	1.03E+07	4.49E+05	Ar 9.74	9.74	0
88	AD8629 dut5 sn2	125	8/31/2011 10:51	1.03E+07	4.67E+05	Ar 9.74	9.74	0
89	AD8629 dut7 sn11	125	8/31/2011 10:55	4.65E+06	4.08E+05	Ar 9.74	9.74	0
90	AD8629 dut7 sn11	125	8/31/2011 10:58	1.04E+07	3.87E+05	Ar 9.74	9.74	0
91	AD8629 dut7 sn11	125	8/31/2011 11:04	1.02E+07	3.90E+05	Ar 9.74	14.56	48
92	AD8629 dut5 sn2	125	8/31/2011 11:10	1.02E+07	3.57E+05	Ar 9.74	14.56	48
93	AD8629 dut5 sn2	125	8/31/2011 11:19	1.82E+05	9.35E+03	Cu 21.17	21.17	0
94	AD8629 dut5 sn2	125	8/31/2011 11:21	2.65E+05	1.01E+04	Cu 21.17	21.17	0
95	AD8629 dut5 sn2	125	8/31/2011 11:22	6.93E+04	9.69E+03	Cu 21.17	21.17	0
96	AD8629 dut5 sn2	125	8/31/2011 11:24	4.79E+05	8.94E+03	Cu 21.17	21.17	0
97	AD8629 dut6 sn3	85	8/31/2011 11:31	1.01E+06	9.55E+03	Cu 21.17	21.17	0
98	AD8629 dut6 sn3	85	8/31/2011 11:34	1.04E+06	1.01E+04	Cu 21.17	21.17	0
100	AD8629 dut8 sn12	85	8/31/2011 11:42	1.01E+06	8.26E+03	Cu 21.17	21.17	0
101	AD8629 dut8 sn12	85	8/31/2011 11:48	1.10E+06	1.54E+05	Kr 30.86	30.86	0
102	AD8629 dut8 sn12	85	8/31/2011 11:49	1.95E+05	1.61E+04	Kr 30.86	30.86	0
103	AD8629 dut8 sn12	85	8/31/2011 11:50	2.86E+05	3.77E+04	Kr 30.86	30.86	0
104	AD8629 dut8 sn12	125	8/31/2011 11:52	1.65E+05	1.39E+04	Kr 30.86	30.86	0
105	AD8629 dut8 sn12	125	8/31/2011 11:53	1.19E+05	8.83E+03	Kr 30.86	30.86	0
106	AD8629 dut7 sn11	85	8/31/2011 11:56	7.66E+04	2.34E+04	Kr 30.86	30.86	0
107	AD8629 dut7 sn11	85	8/31/2011 11:57	3.81E+05	1.74E+04	Kr 30.86	30.86	0

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5.0. Single Event Latch-Up Test Results

The AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (of the lot date code identified on the first page of this report) is susceptible to SEL events at various LETs as a function of case temperature. None of the events were observed to be destructive (i.e. all of the units-under-test continued to pass gross functionality following a power cycle), when using a current limit of 200mA and removing power within 10s from the beginning of the event. The following general results were obtained during the course of the testing:

1. The units pass SEL testing at a maximum LET of approximately 14.5MeV-cm^2/mg at an elevated case temperature of 125ºC, but failed at the next highest measured LET of 21MeV-cm^2/mg.
2. The units pass SEL testing at a maximum LET of approximately 21MeV-cm^2/mg at an elevated case temperature of 85ºC, but failed at the next highest measured LET of approximately 31MeV-cm^2/mg.
3. The units pass SEL testing at a maximum LET of approximately 31MeV-cm^2/mg at a case temperature of approximately 25ºC (ambient room temperature of Cave 4B at Berkeley National Laboratories), but failed at the next highest measured LET of approximately 59MeV-cm^2/mg

Table 5.1 show a summary of the single event latch-up data acquired. The table shows the part type (AD8629), the serial number of the part irradiated, the test configuration (all units irradiated in a static configuration), the case temperature during testing, the ion species, the effective fluence, the effective LET, the number of SEL events recorded and the SEL cross-section. 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 the testing and, therefore, TID damage did not play a significant role in these results.

Figures 5.1 and 5.2 show the supply current data during the SEL runs. In these figures the supply current (positive and negative 2.5V power supplies) are 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 a sharp increase 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 AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier

Run#	DUT	Temp (degC)	Total Eff Fluence	Ion	Eff LET	Angle	SEL Cross-Section	Comments
80	DUT8 SN12	25	3.16E+05	Xe 58.78	58.78	0	3.16E-06	Latchup
83	DUT6 SN3	25	1.02E+06	Kr 30.86	30.86	0	N/A	No Latchup
84	DUT5 SN2	25	1.02E+07	Kr 30.86	30.86	0	N/A	No Latchup
85	DUT5 SN2	90	3.04E+06	Kr 30.86	30.86	0	3.29E-07	Latchup
86	DUT5 SN2	85	1.03E+07	Ar 9.74	9.74	0	N/A	No Latchup
88	DUT5 SN2	125	1.03E+07	Ar 9.74	9.74	0	N/A	No Latchup
89	DUT7 SN11	125	4.65E+06	Ar 9.74	9.74	0	N/A	No Latchup
90	DUT7 SN11	125	1.04E+07	Ar 9.74	9.74	0	N/A	No Latchup
91	DUT7 SN11	125	1.02E+07	Ar 9.74	14.56	48	N/A	No Latchup
92	DUT5 SN2	125	1.02E+07	Ar 9.74	14.56	48	N/A	No Latchup
93	DUT5 SN2	125	1.82E+05	Cu 21.17	21.17	0	5.49E-06	Latchup
94	DUT5 SN2	125	2.65E+05	Cu 21.17	21.17	0	3.77E-06	Latchup
95	DUT5 SN2	125	6.93E+04	Cu 21.17	21.17	0	1.44E-05	Latchup
96	DUT5 SN2	125	4.79E+05	Cu 21.17	21.17	0	2.09E-06	Latchup
97	DUT6 SN3	85	1.01E+06	Cu 21.17	21.17	0	N/A	No Latchup
98	DUT6 SN3	85	1.04E+06	Cu 21.17	21.17	0	N/A	No Latchup
100	DUT8 SN12	85	1.01E+06	Cu 21.17	21.17	0	N/A	No Latchup
101	DUT8 SN12	85	1.10E+06	Kr 30.86	30.86	0	9.09E-07	Latchup
102	DUT8 SN12	85	1.95E+05	Kr 30.86	30.86	0	5.13E-06	Latchup
103	DUT8 SN12	85	2.86E+05	Kr 30.86	30.86	0	3.50E-06	Latchup
104	DUT8 SN12	125	1.65E+05	Kr 30.86	30.86	0	6.06E-06	Latchup
105	DUT8 SN12	125	1.19E+05	Kr 30.86	30.86	0	8.40E-06	Latchup
106	DUT7 SN11	85	7.66E+04	Kr 30.86	30.86	0	1.31E-05	Latchup
107	DUT7 SN11	85	3.81E+05	Kr 30.86	30.86	0	2.62E-06	Latchup

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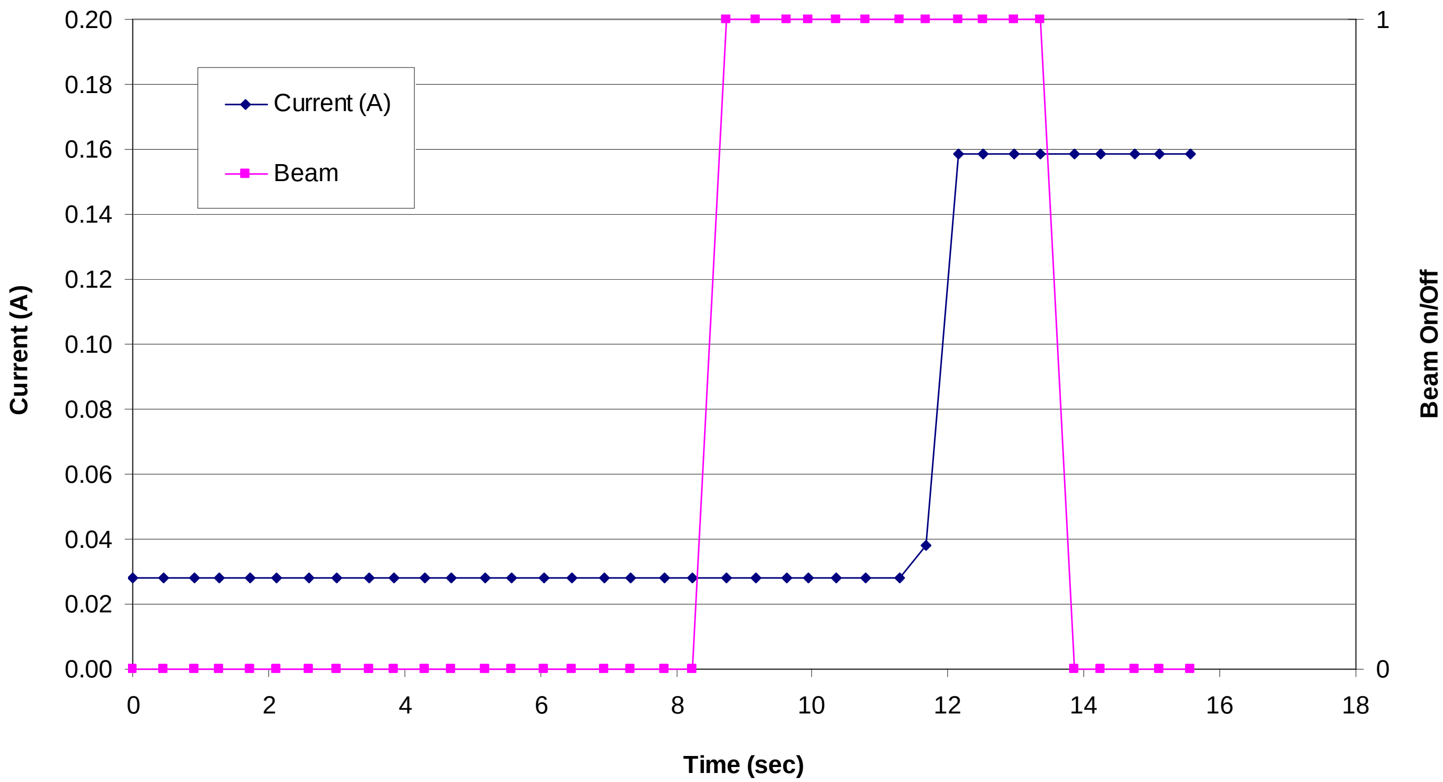

Figure 5.1. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 80, DUT 8, SN12). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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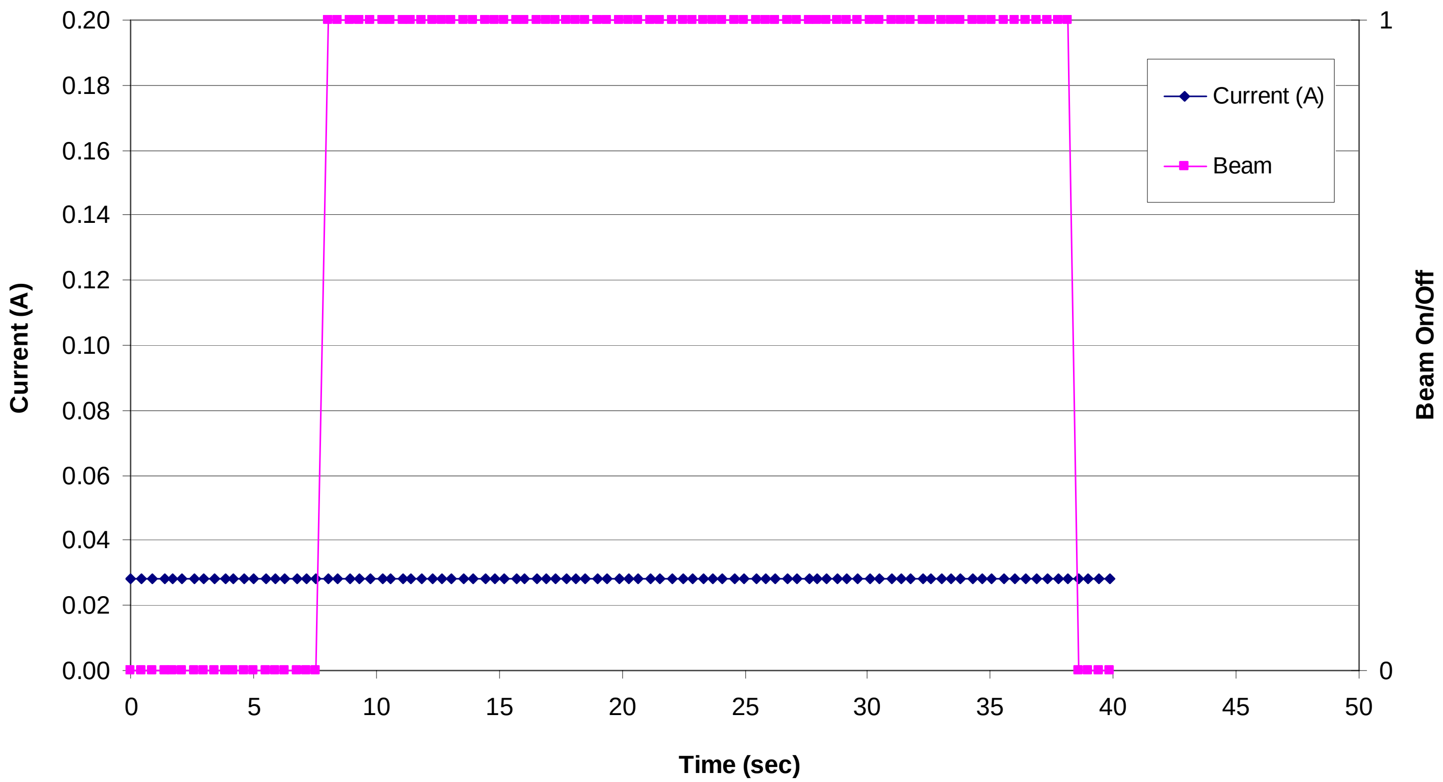

Figure 5.2. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 83, DUT 6, SN3). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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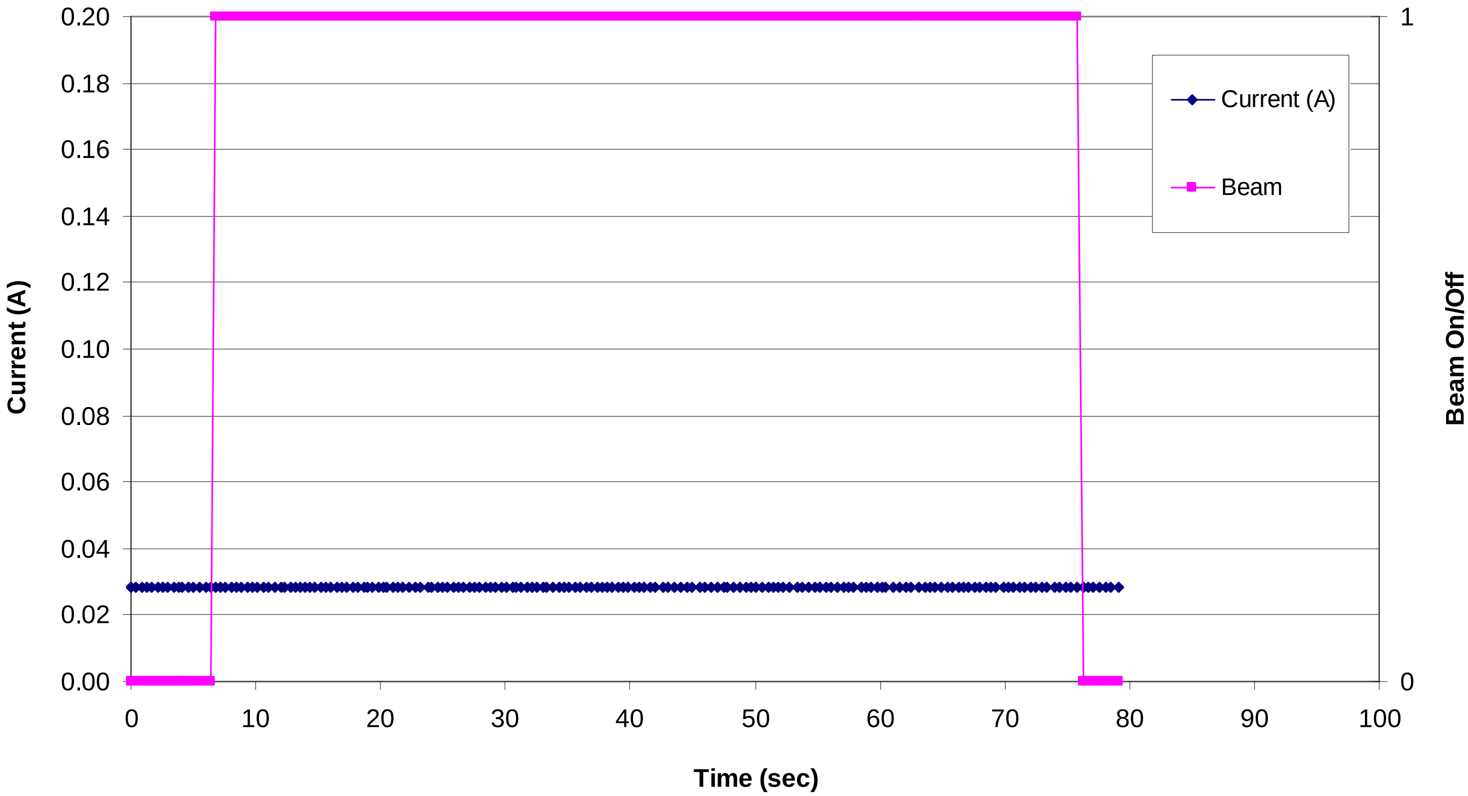

Figure 5.3. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 84, DUT 5, SN2). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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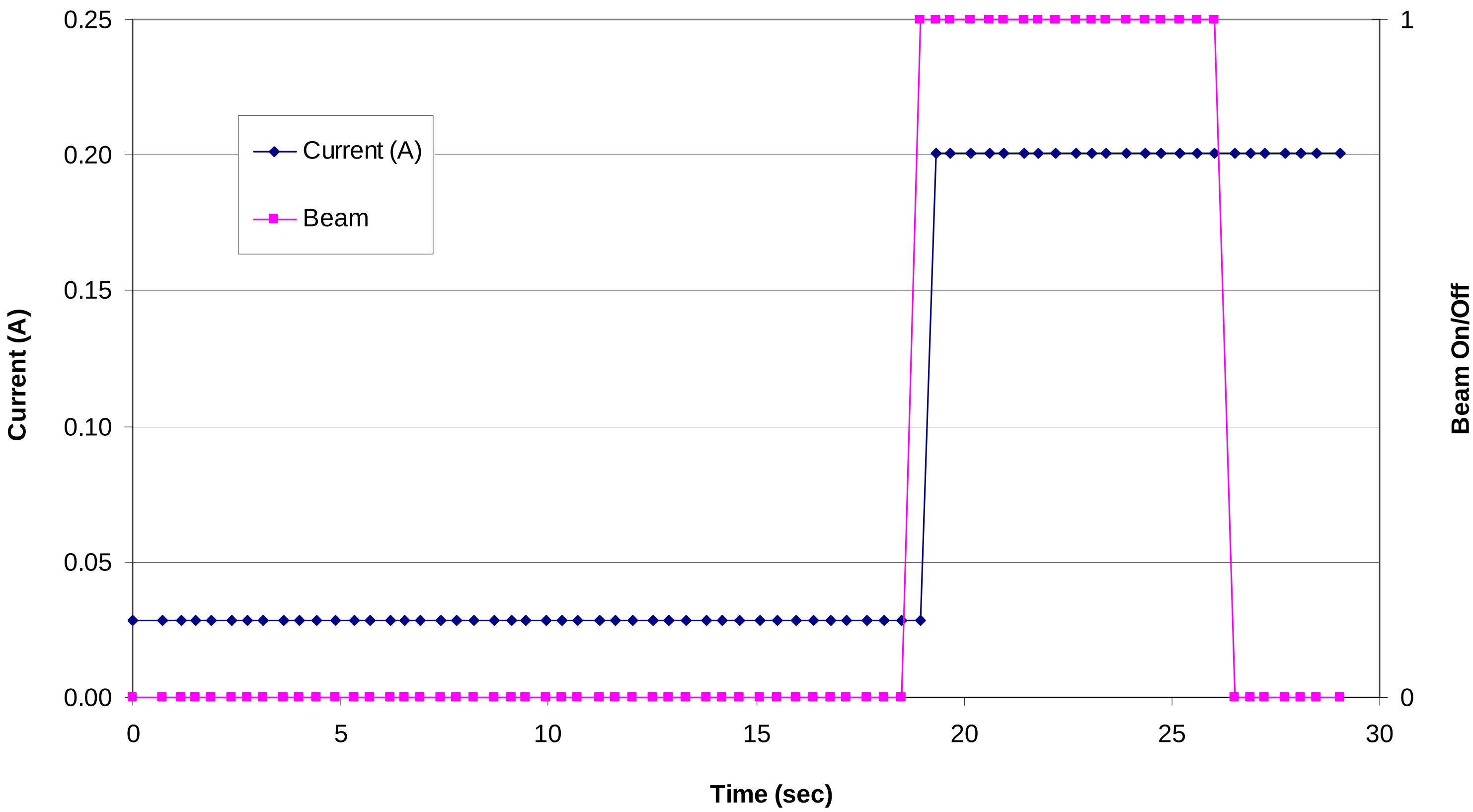

Figure 5.4. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 85, DUT 5, SN2). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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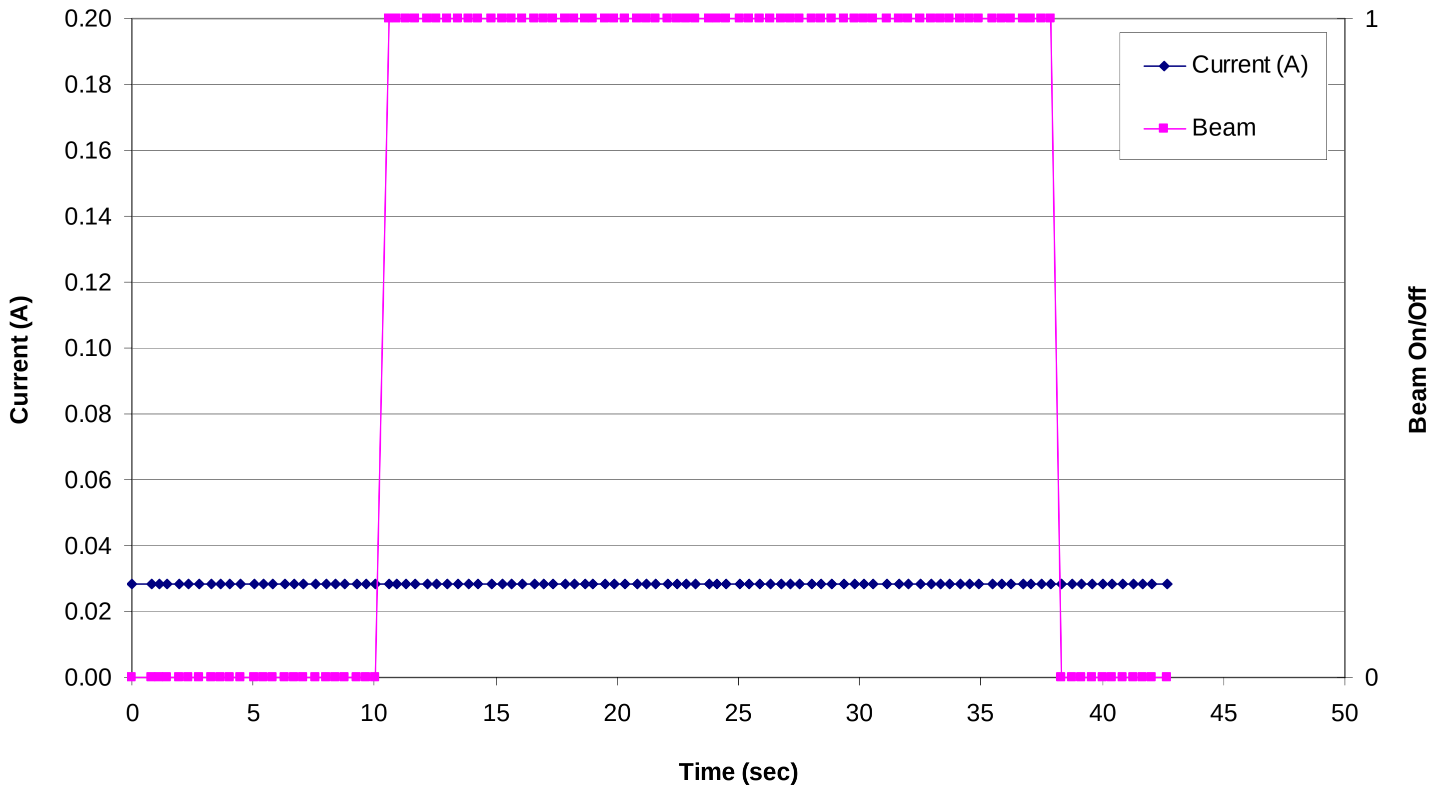

Figure 5.5. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 86, DUT 5, SN2). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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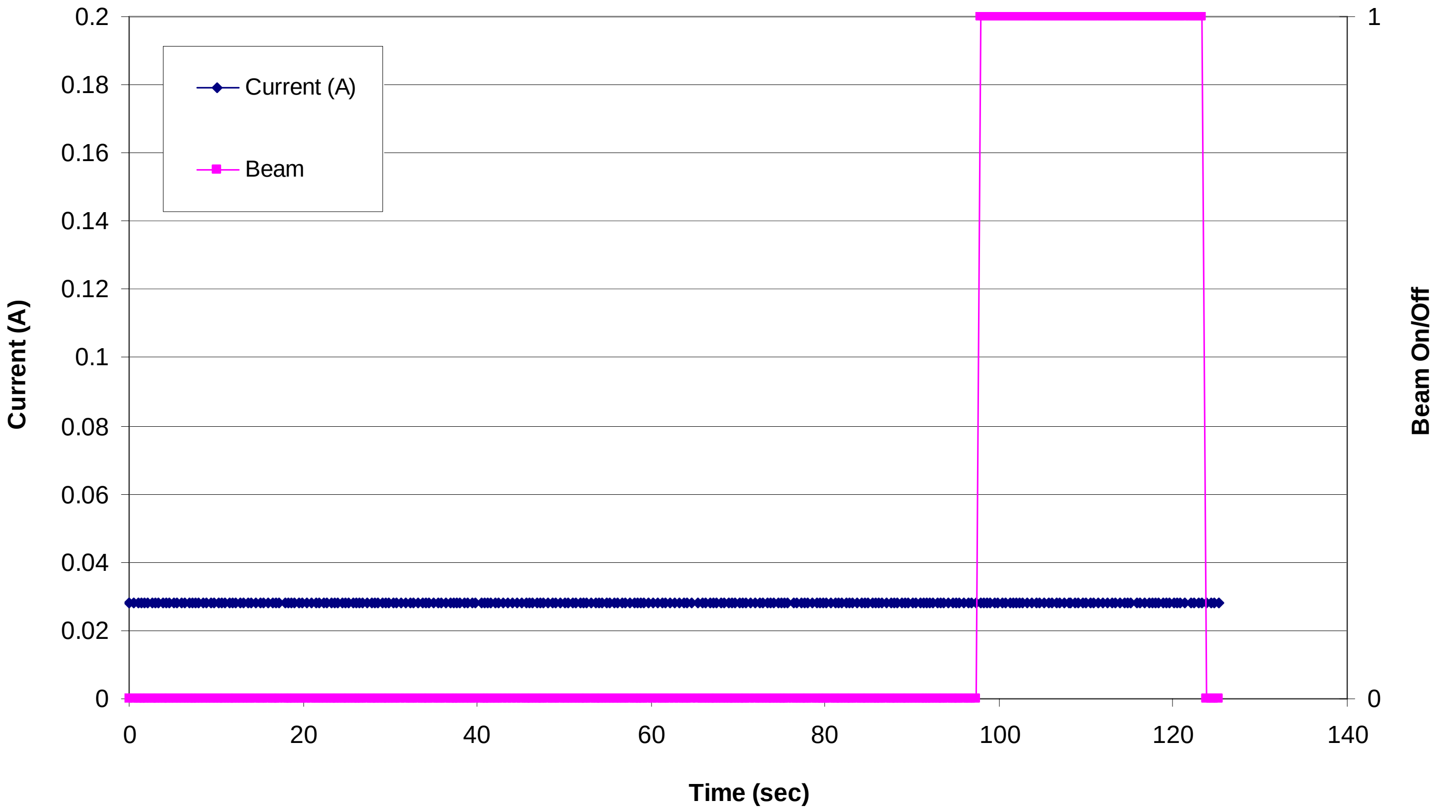

Figure 5.6. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 88, DUT 5, SN2). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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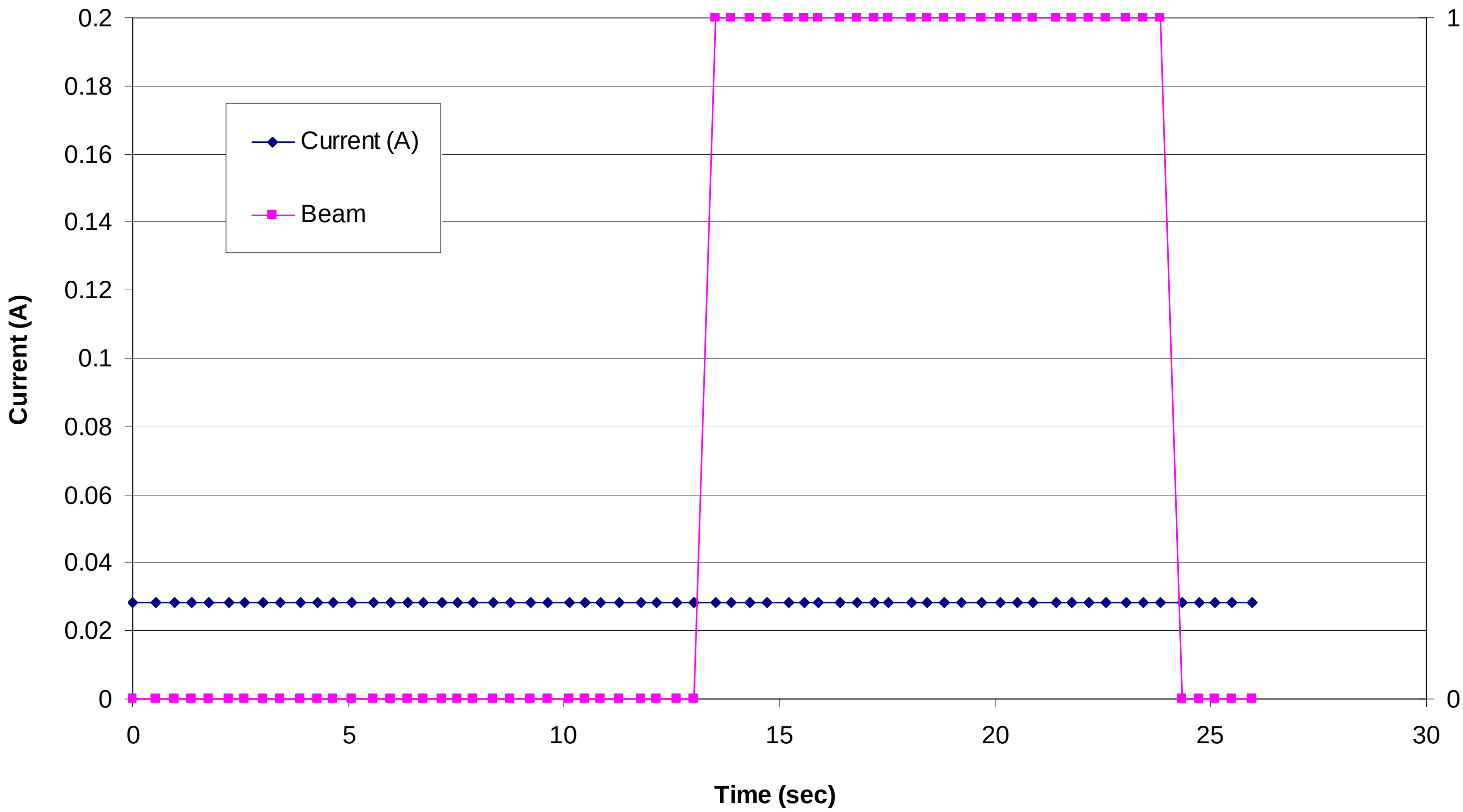

Figure 5.7. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 89, DUT 7, SN11). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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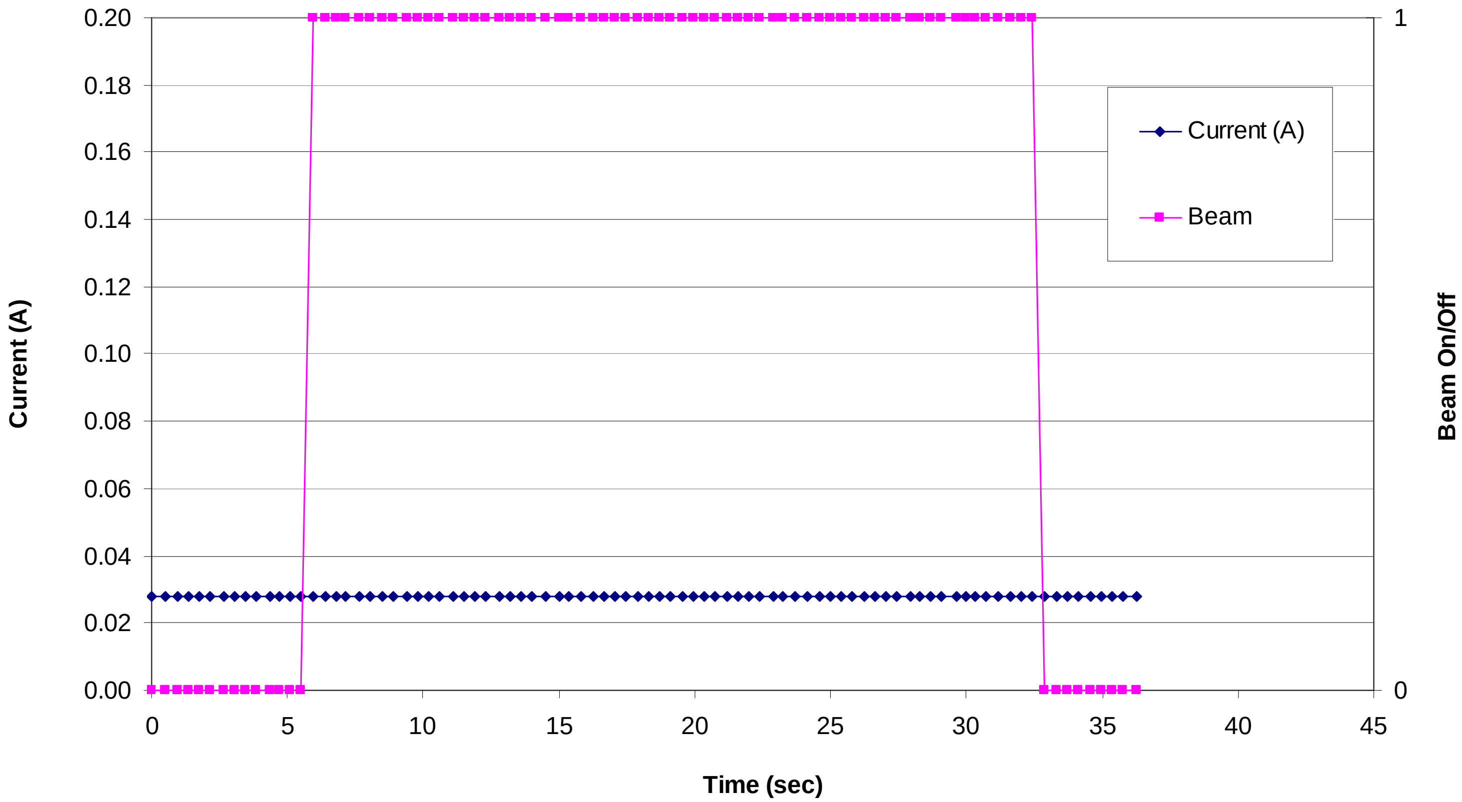

Figure 5.8. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 90, DUT 7, SN11). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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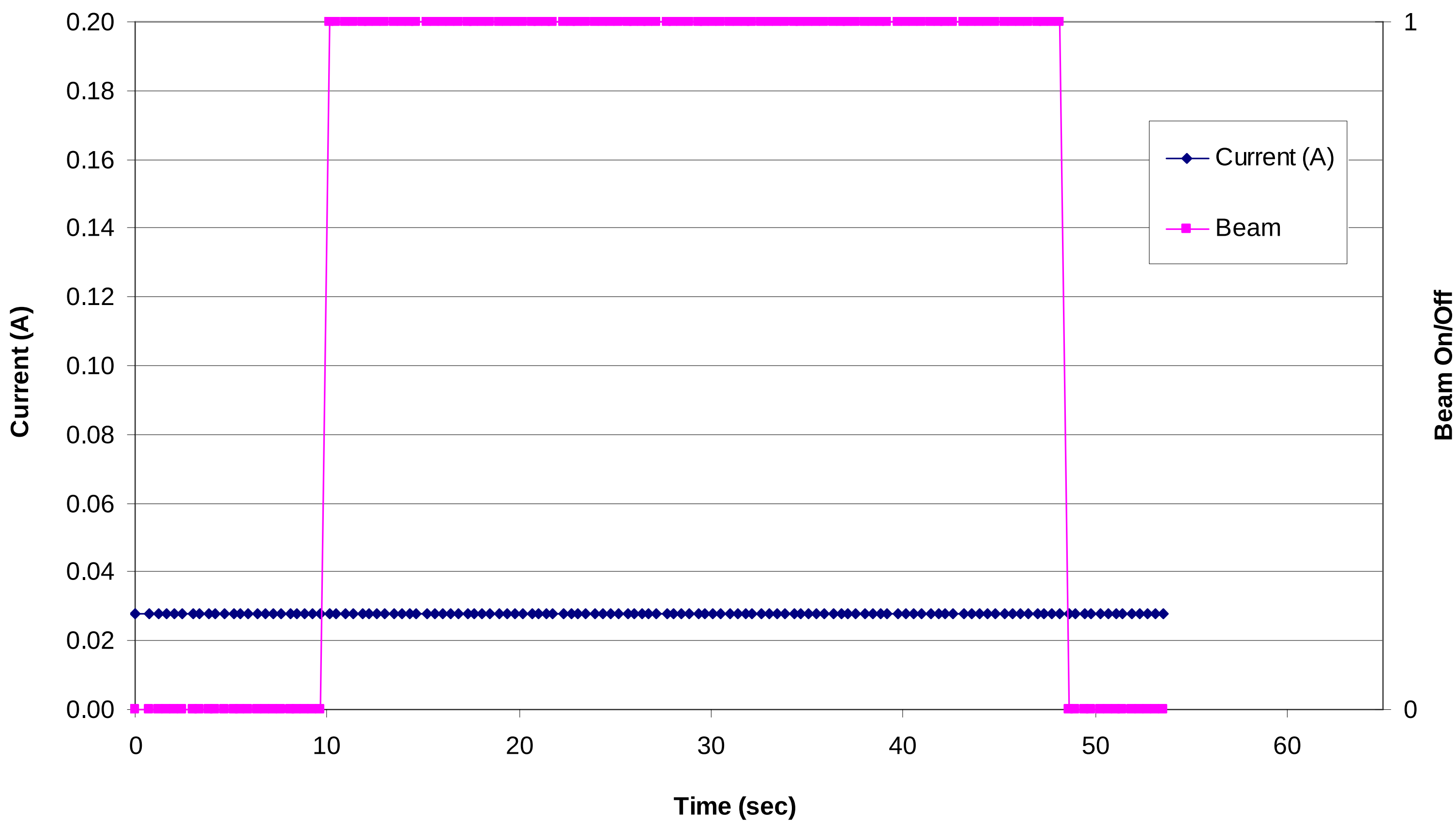

Figure 5.9. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 91, DUT 7, SN11). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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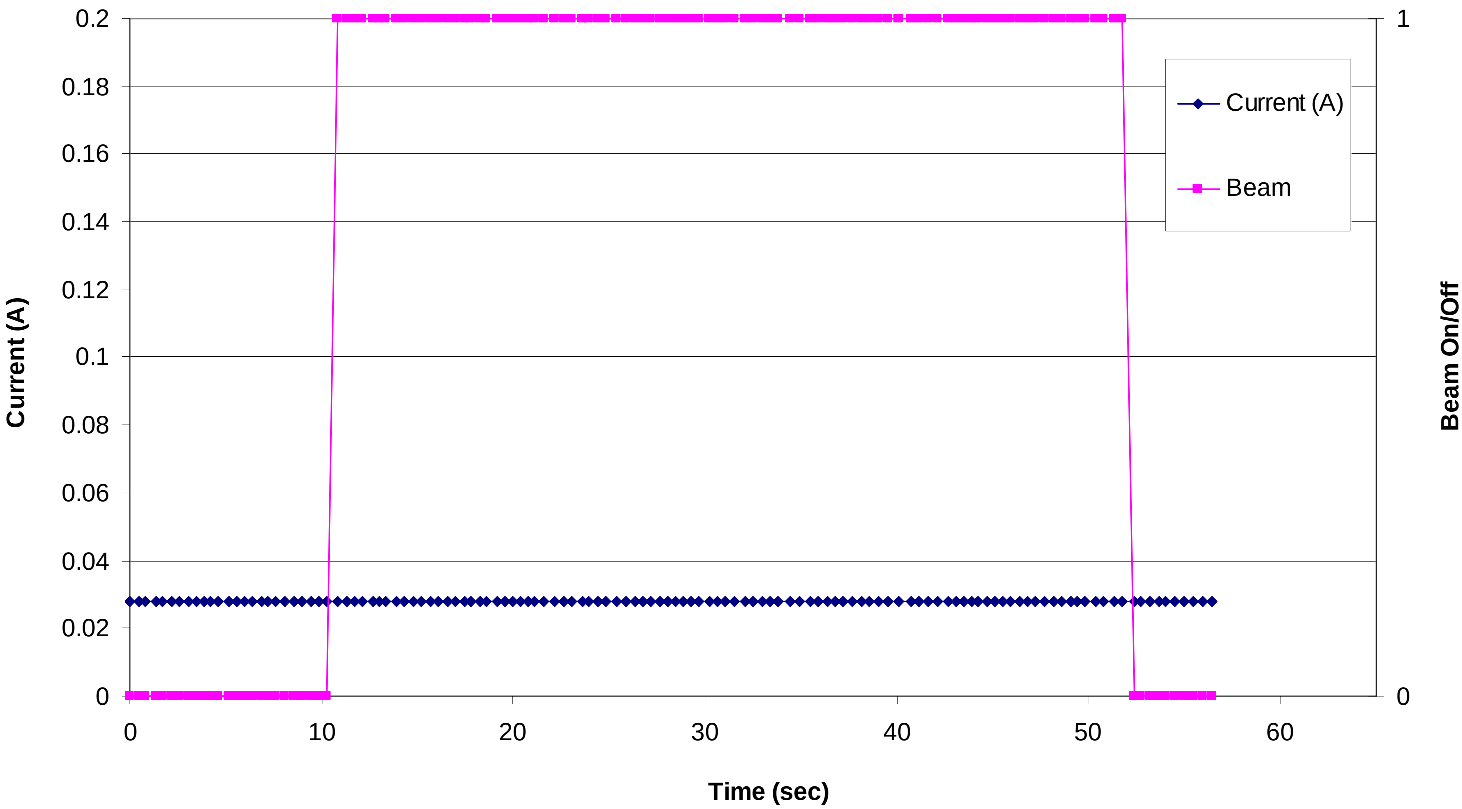

Figure 5.10. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 92, DUT 5, SN2). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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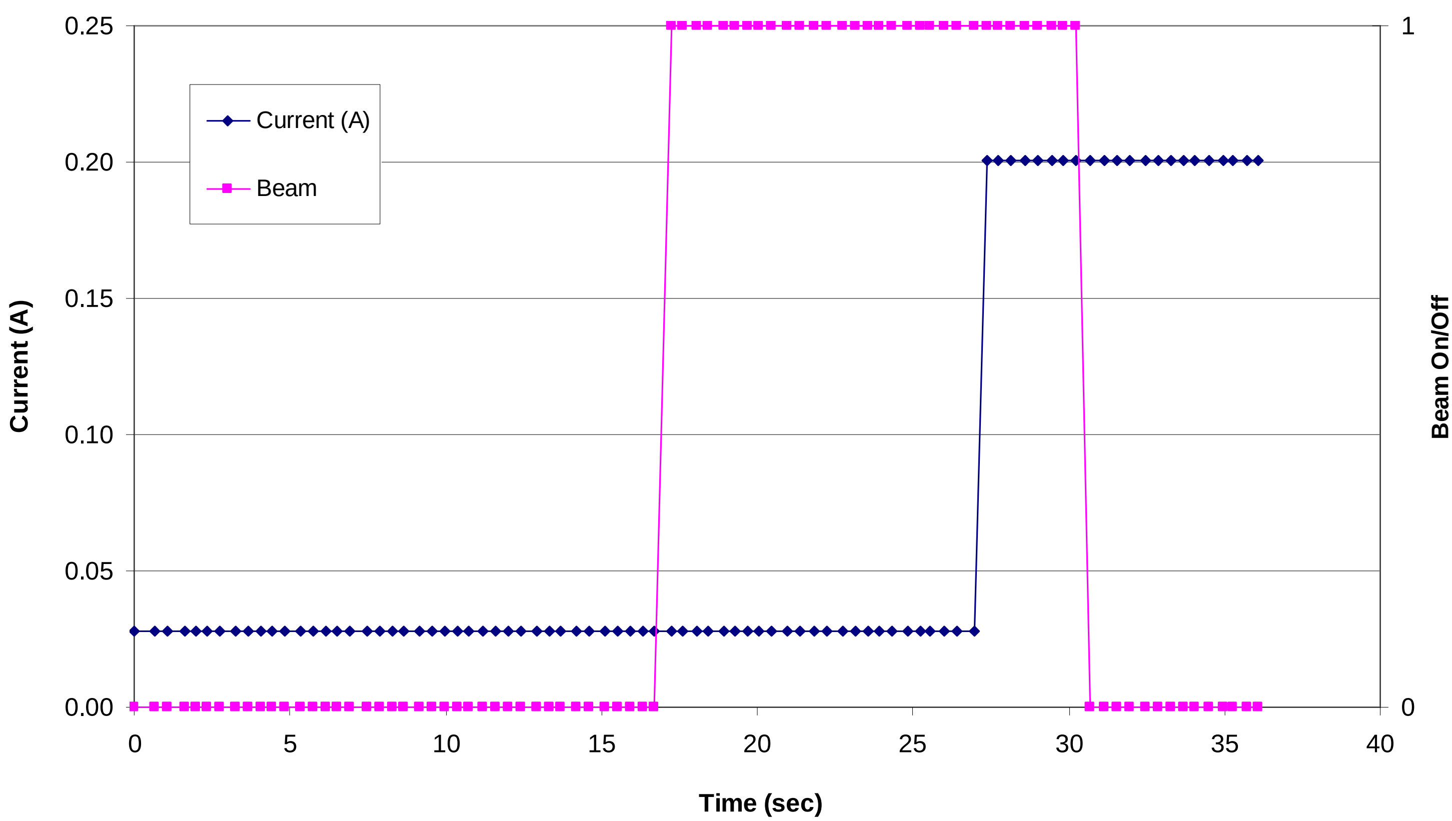

Figure 5.11. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 93, DUT 5, SN2). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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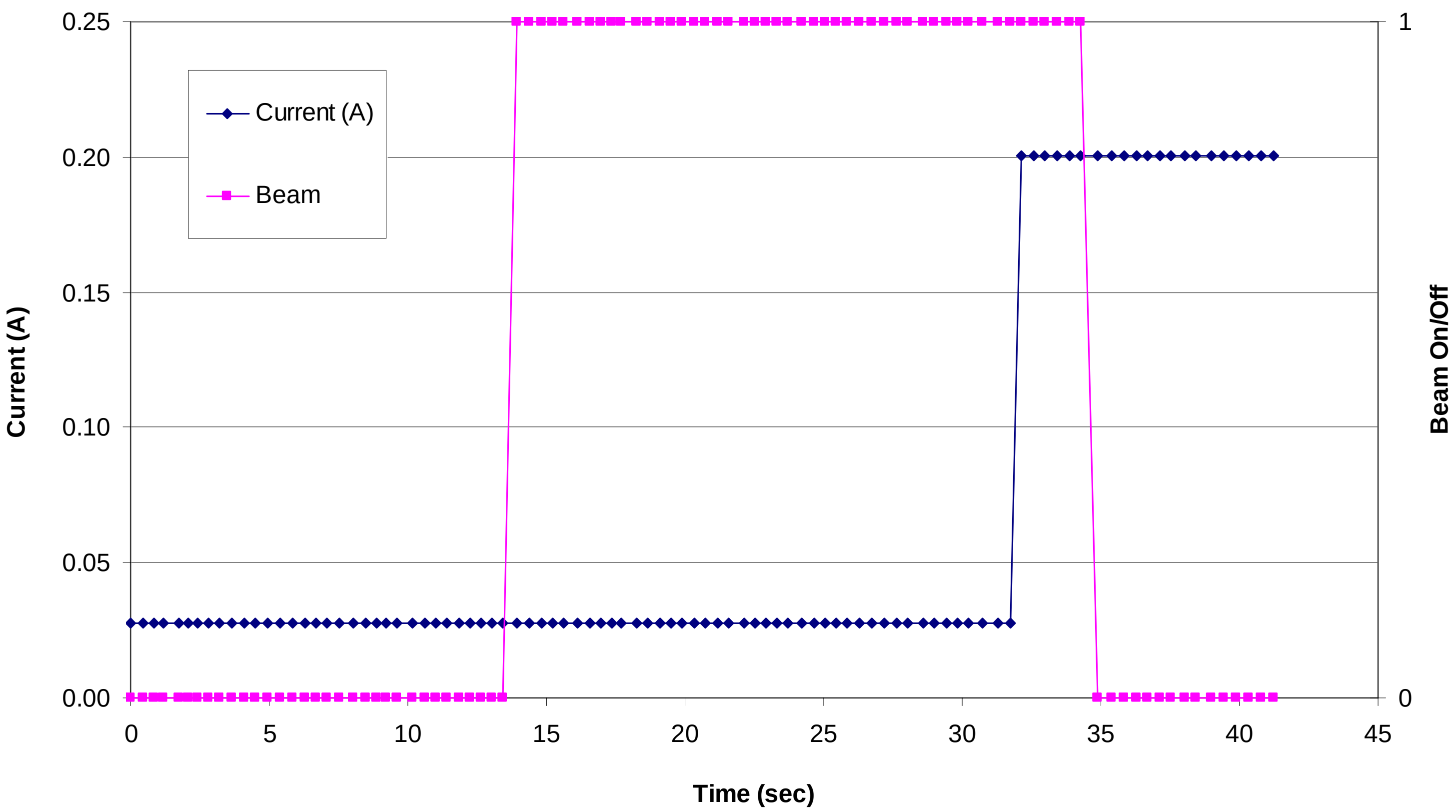

Figure 5.12. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 94, DUT 5, SN2). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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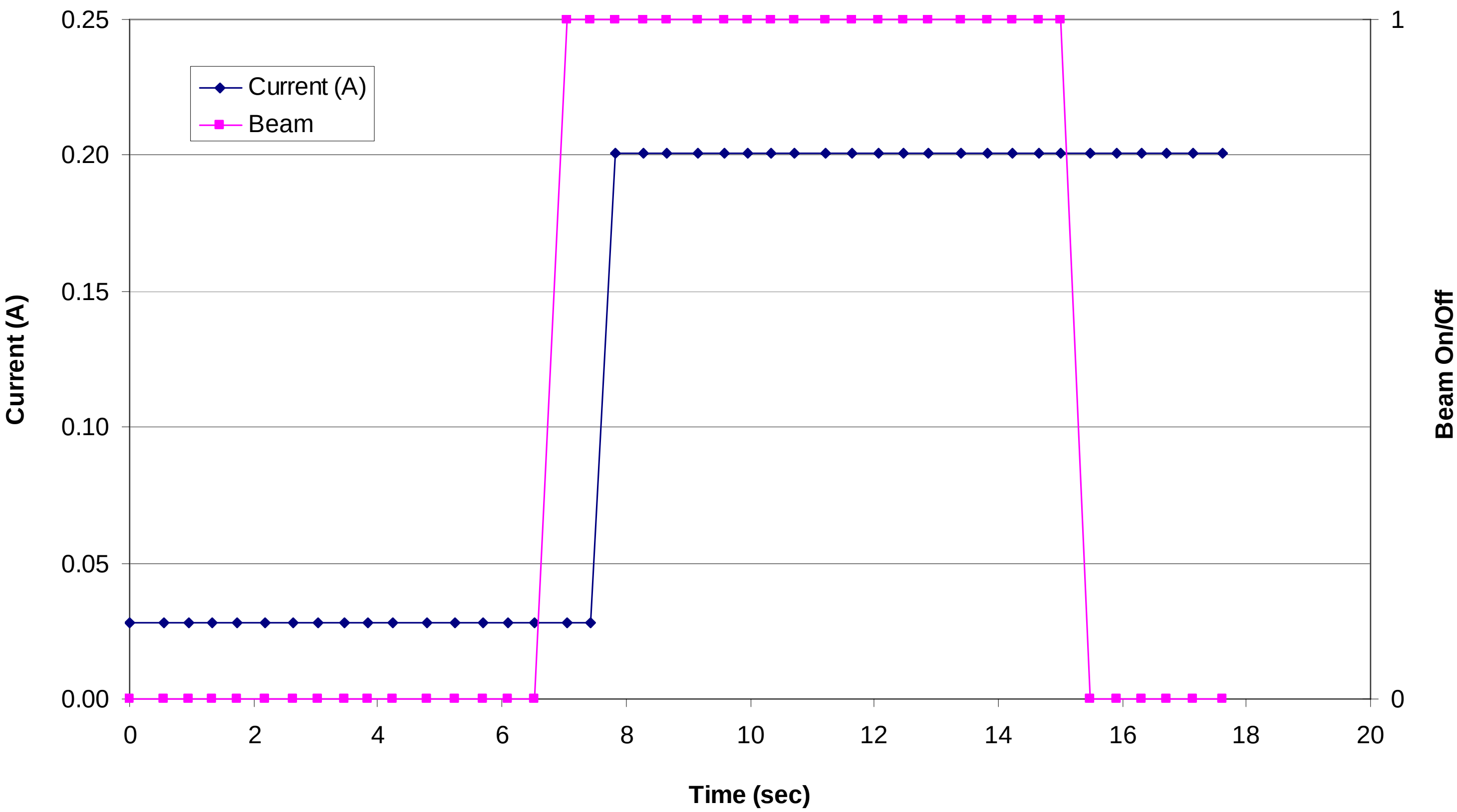

Figure 5.13. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 95, DUT 5, SN2). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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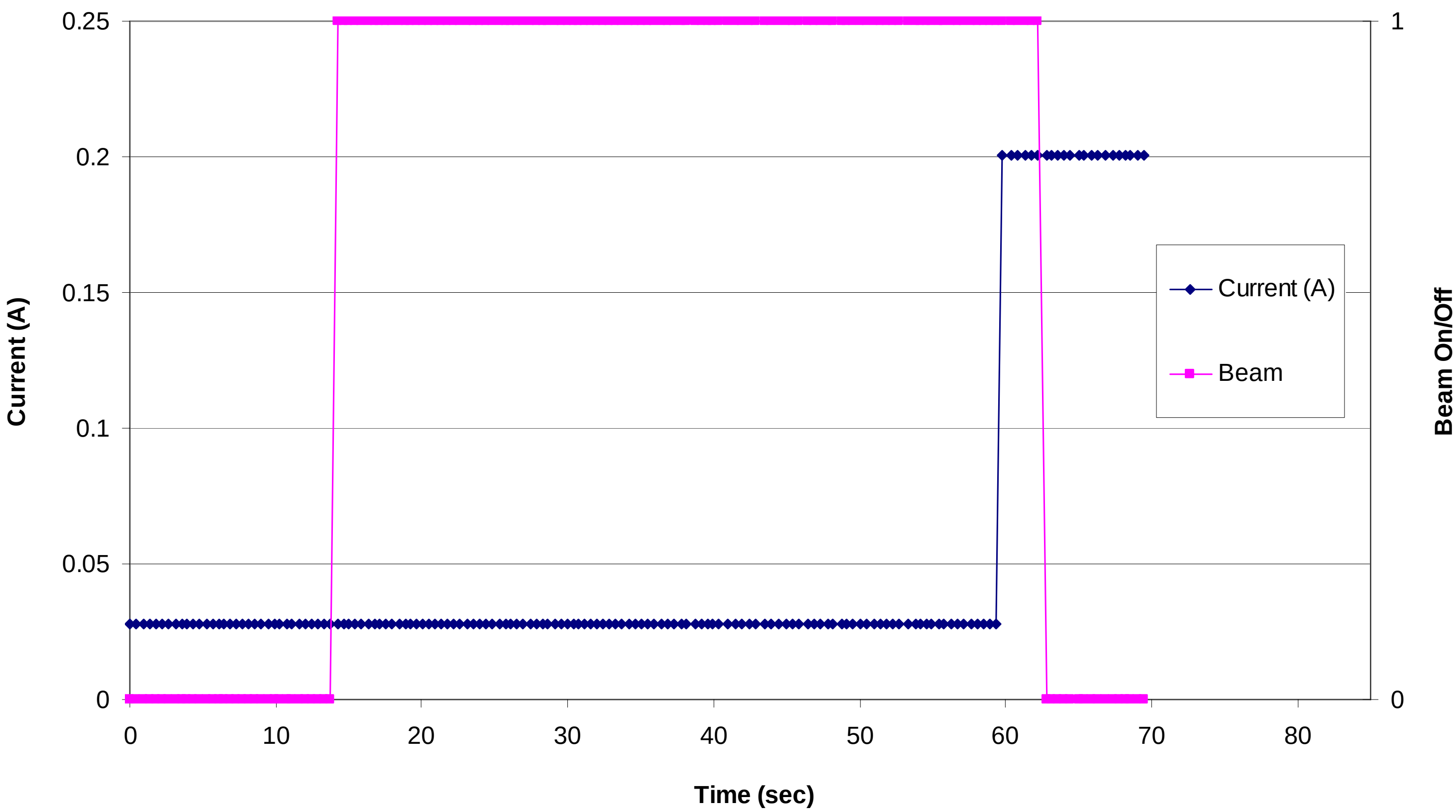

Figure 5.14. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 96, DUT 5, SN2). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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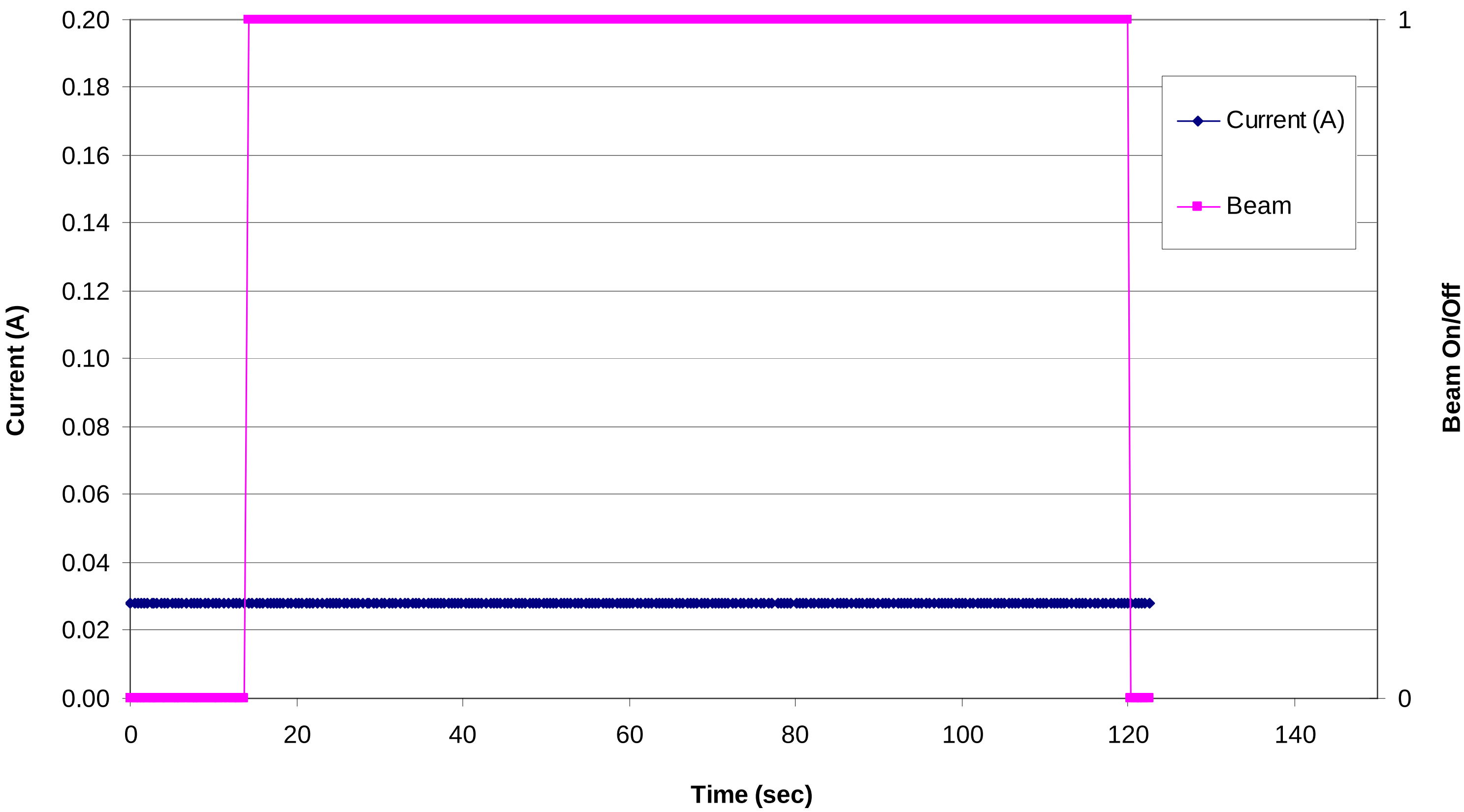

Figure 5.15. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 97, DUT 6, SN3). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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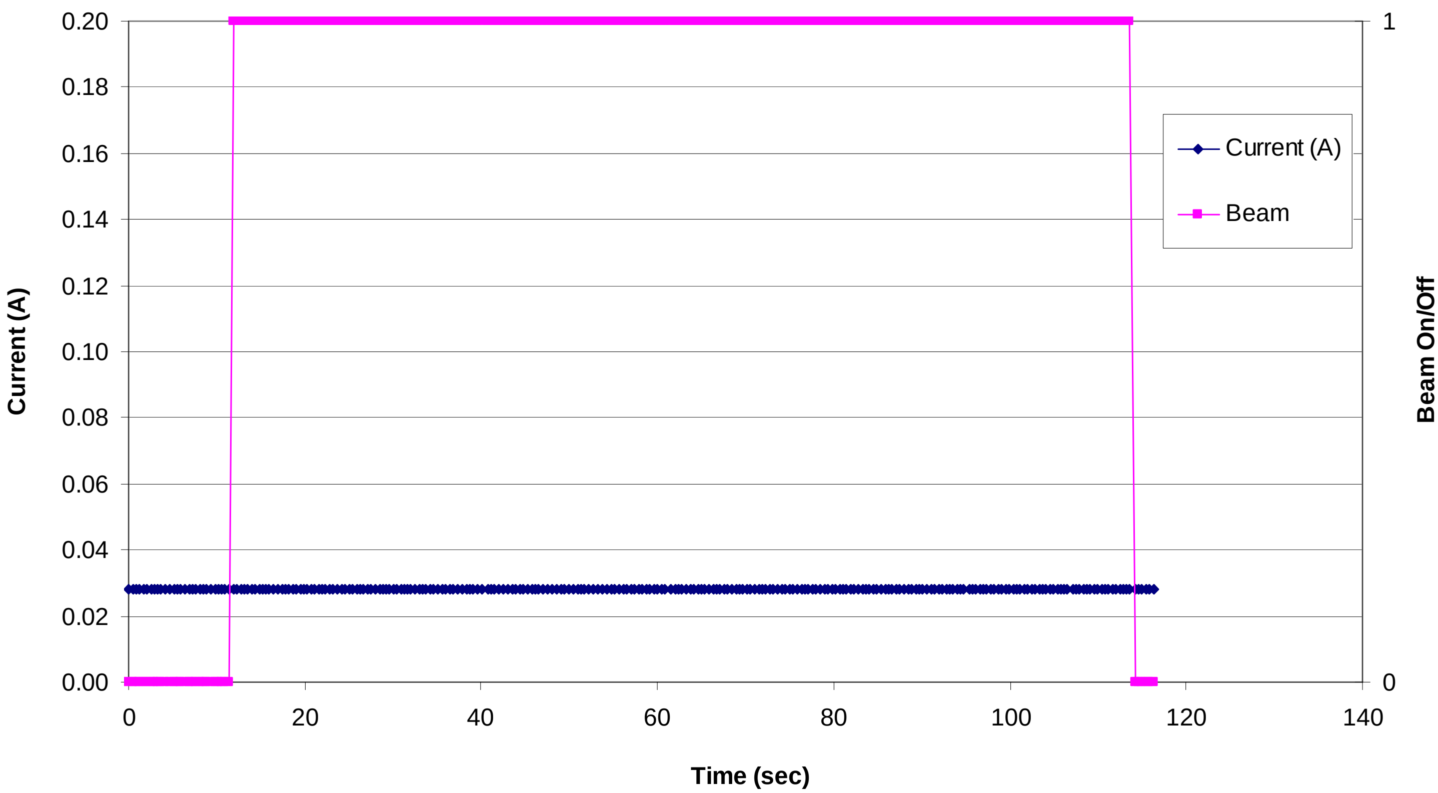

Figure 5.16. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 98, DUT 6, SN3). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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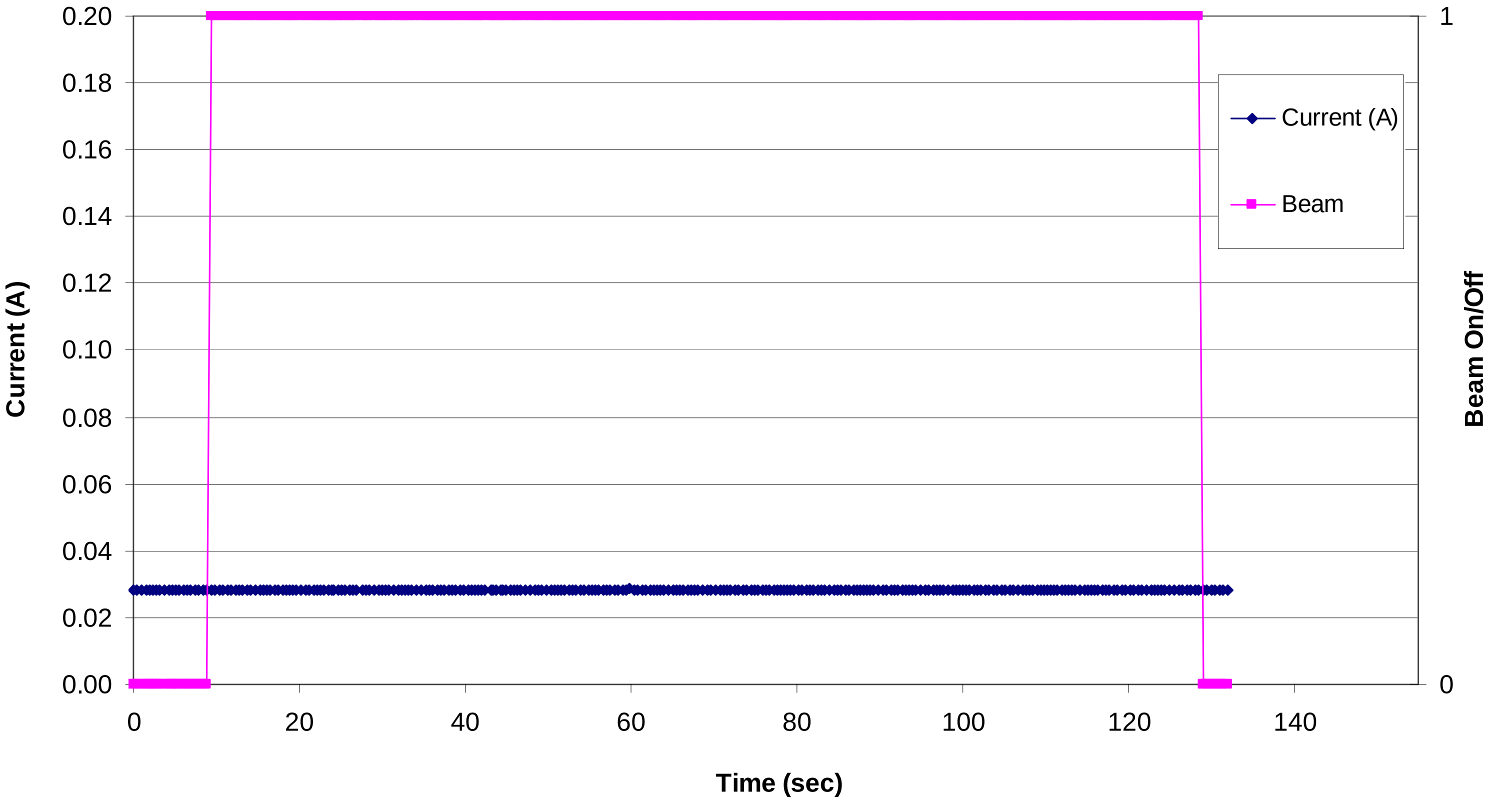

Figure 5.17. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 100, DUT 8, SN12). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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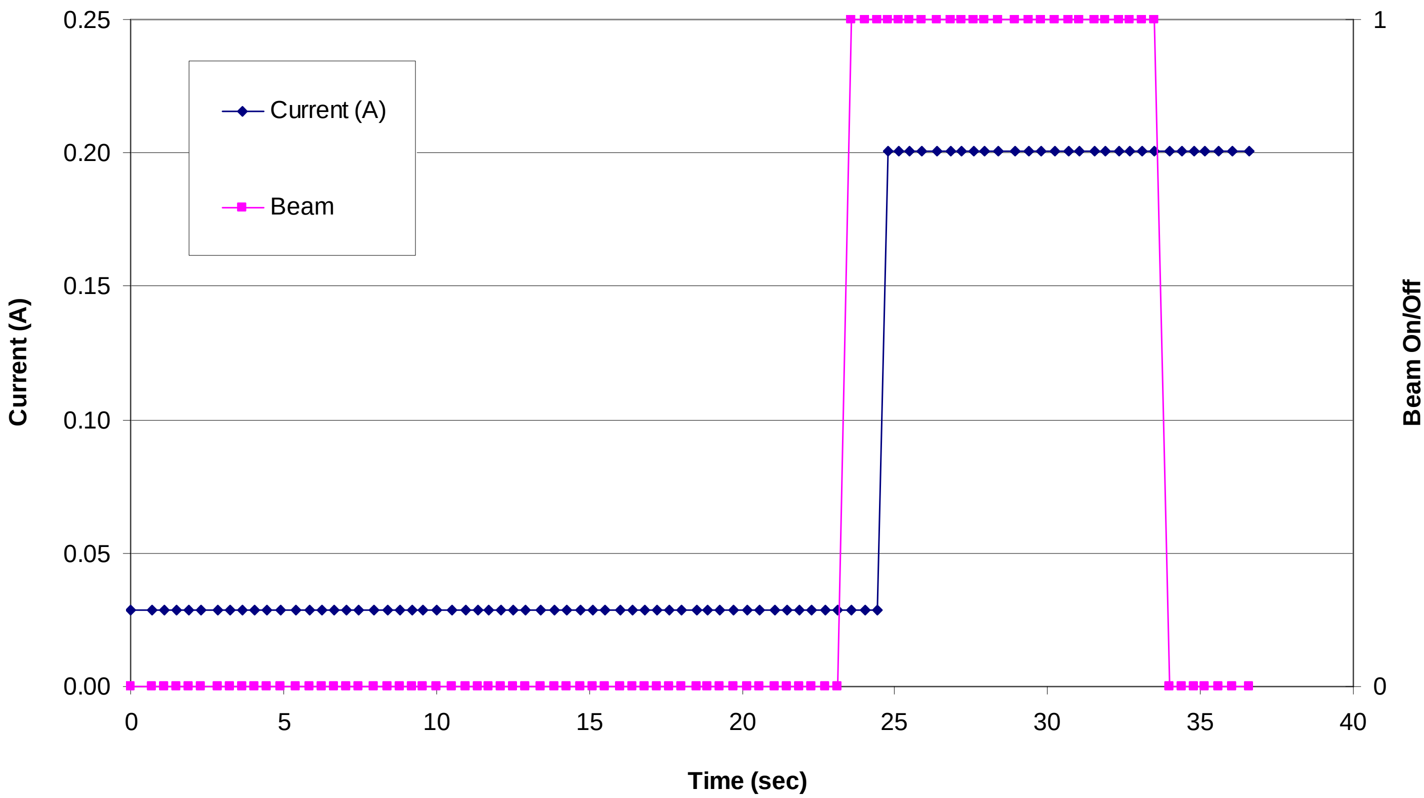

Figure 5.18. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 101, DUT 8, SN12). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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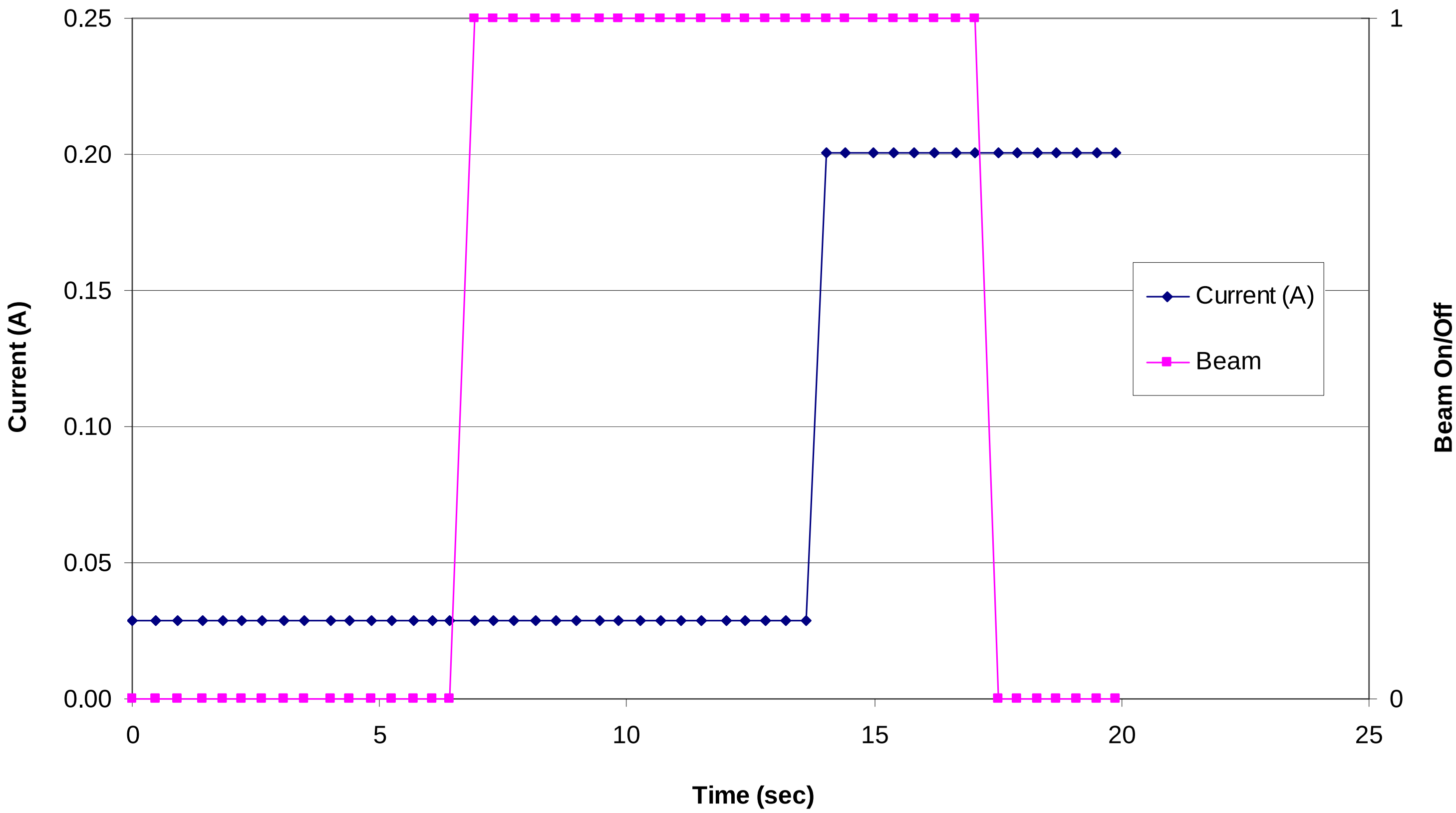

Figure 5.19. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 102, DUT 8, SN12). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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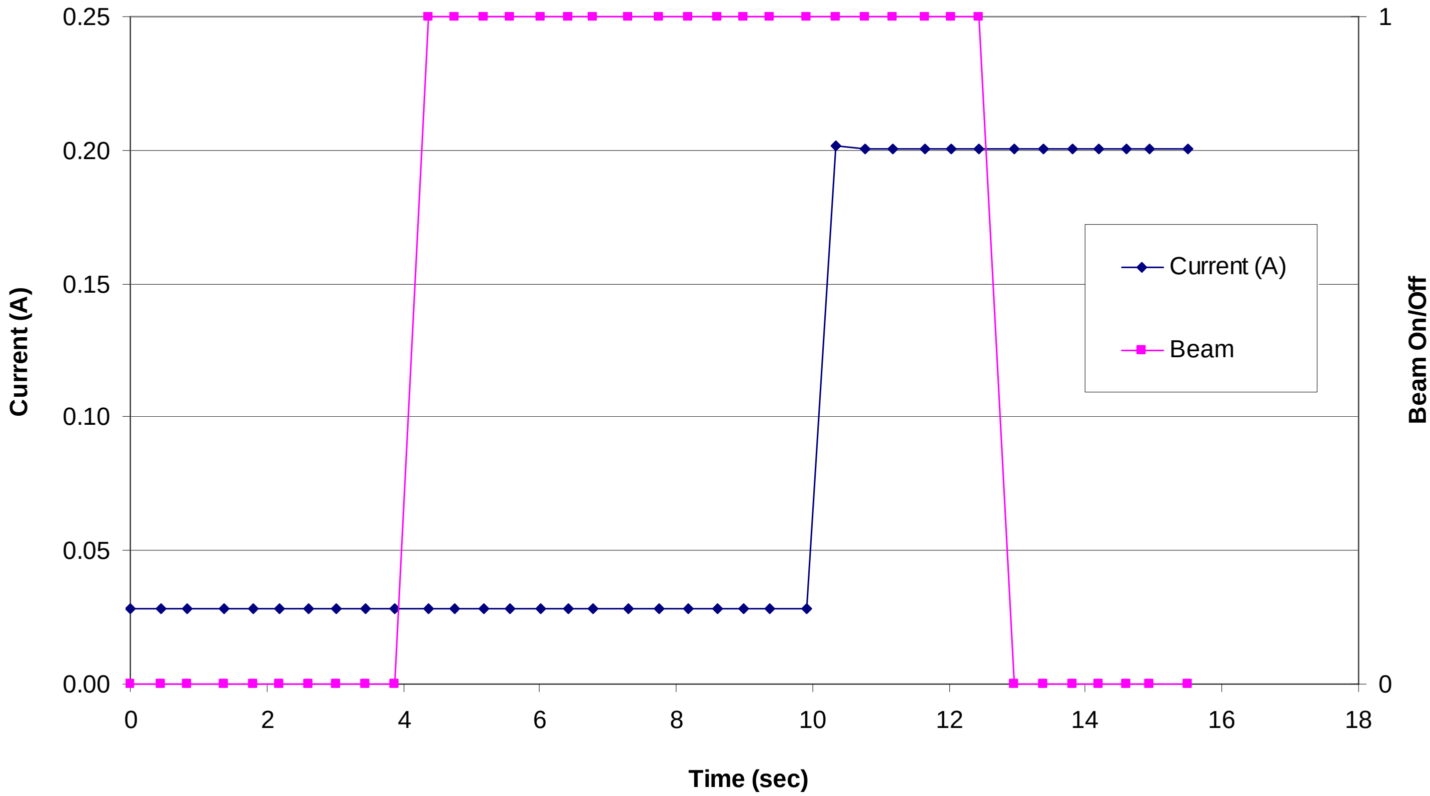

Figure 5.20. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 103, DUT 8, SN12). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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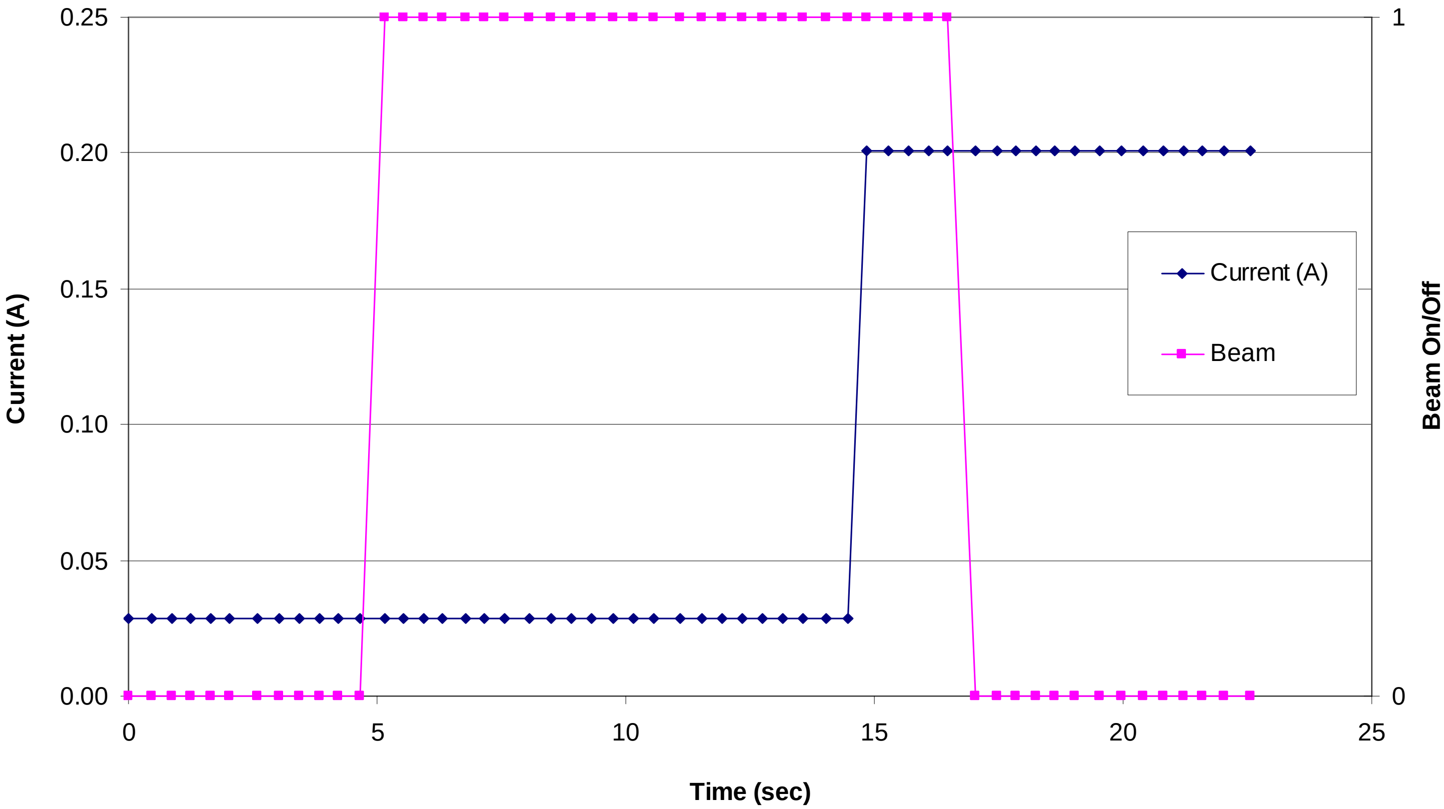

Figure 5.21. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 104, DUT 8, SN12). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A "0" indicates the shutter is closed (beam off) and a "1" indicates that the shutter is open (beam on).

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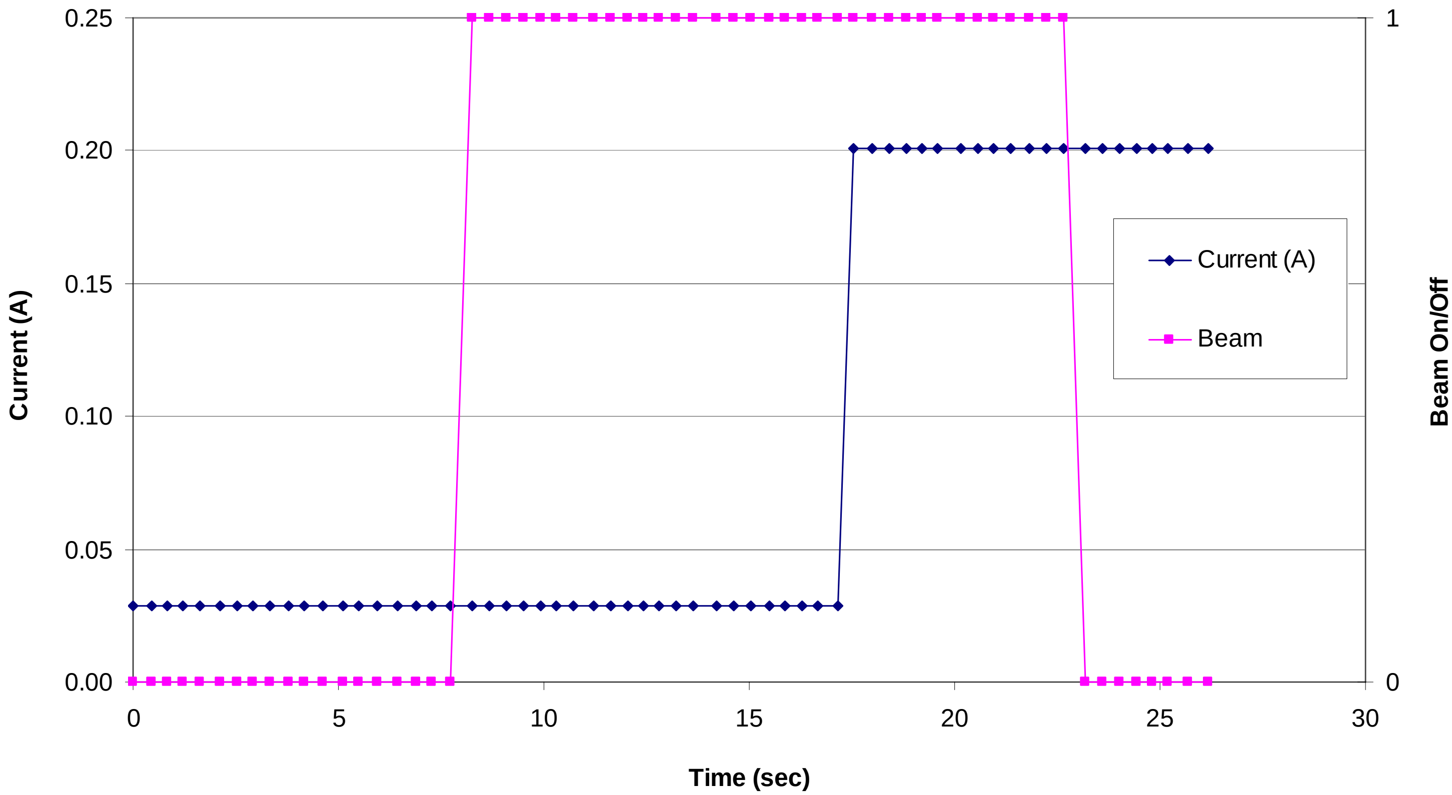

Figure 5.22. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 105, DUT 8, SN12). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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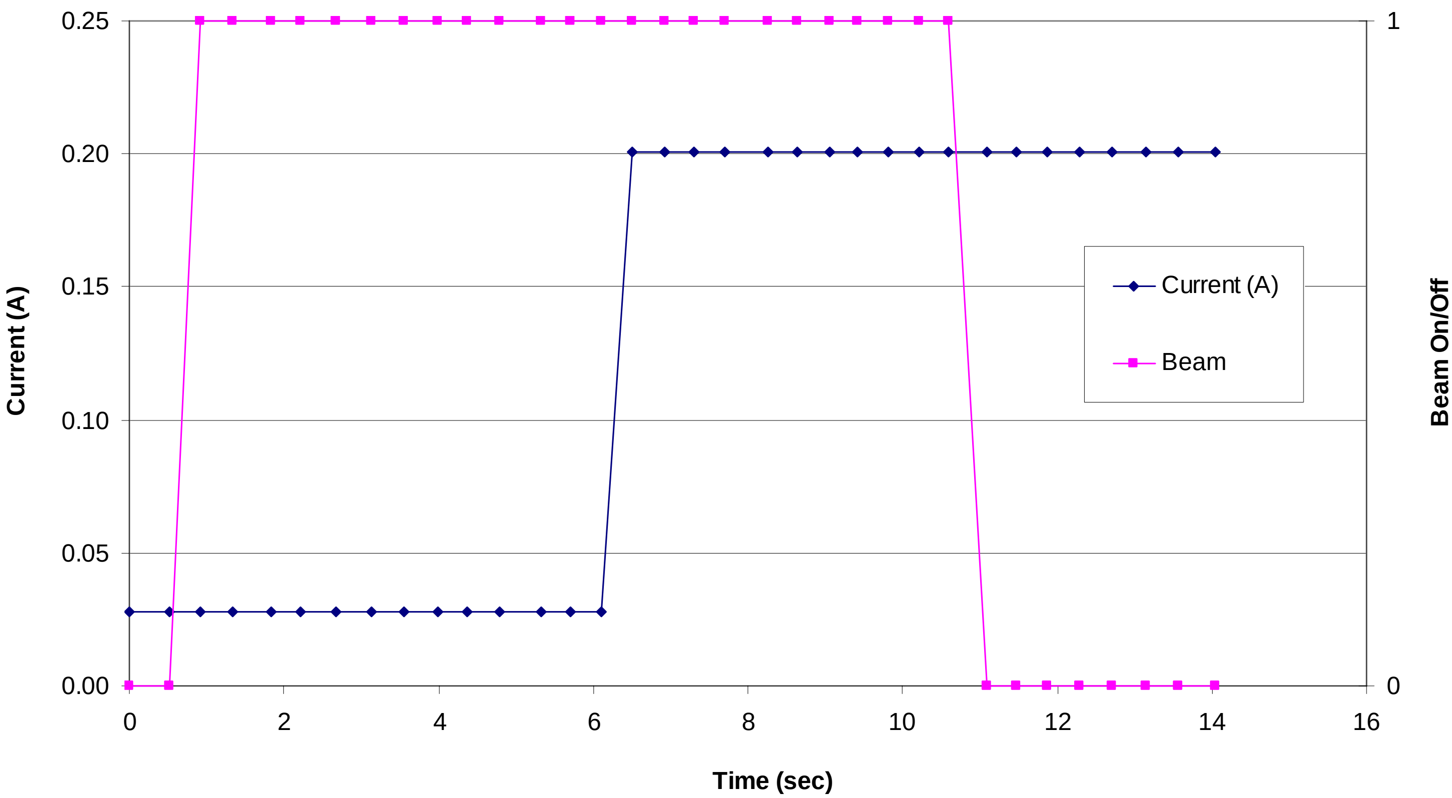

Figure 5.23. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 106, DUT 7, SN11). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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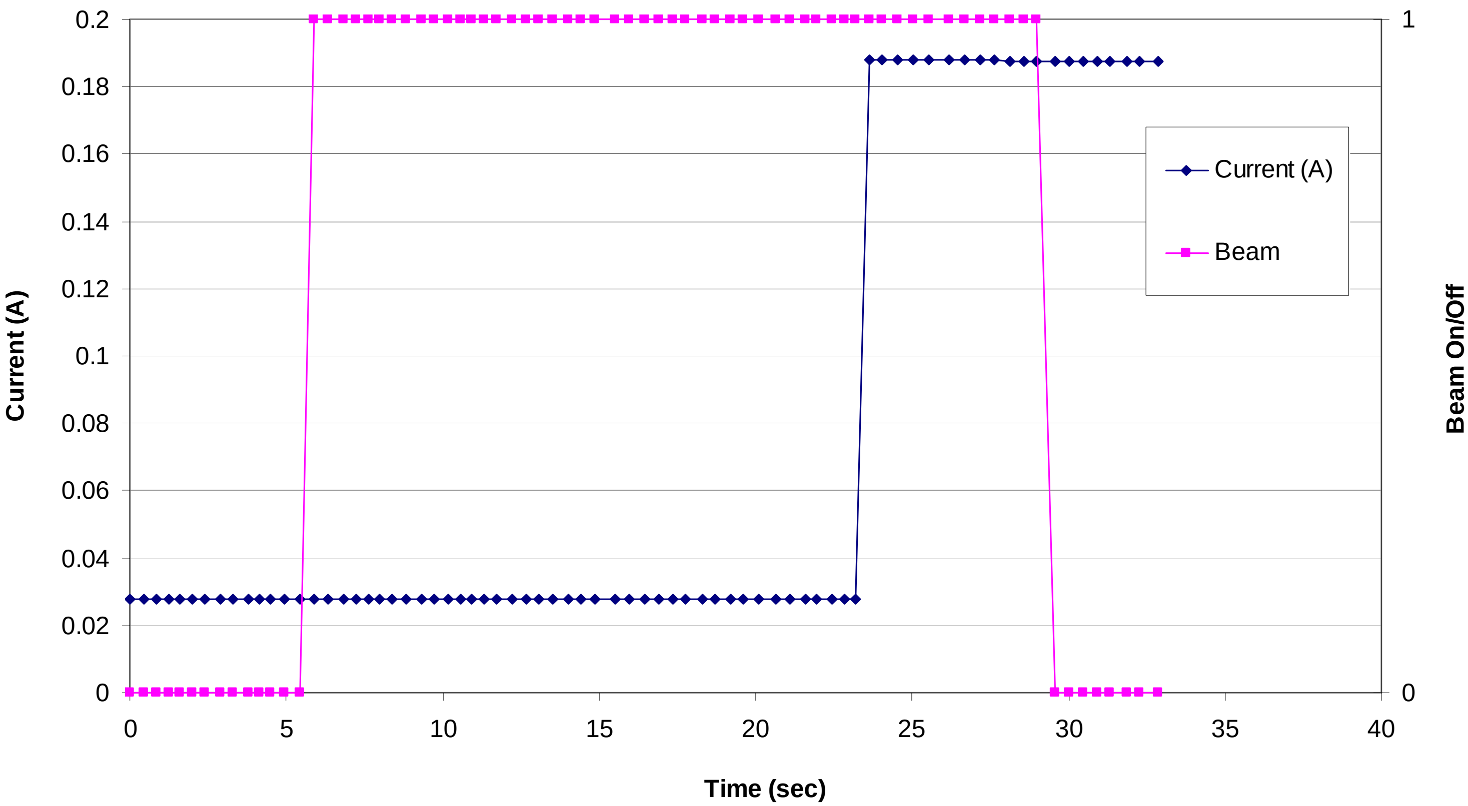

Figure 5.24. Input supply current versus time/fluence for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 107, DUT 7, SN11). See Table 4.1 for the details of the test conditions. In this figure the dark blue data points represent the input supply current and the magenta data points represent the beam condition (beam on/beam off). A “0” indicates the shutter is closed (beam off) and a “1” indicates that the shutter is open (beam on).

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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.

The AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier described in this final report was irradiated using the 10MeV/n Xe, Kr, Cu and Ar using a single ended supply voltage of 5V and at three case temperatures of 125°C, 85°C and 25°C (±5°C). Figure 3.1 shows the test board used for the SEL testing described in this final report. The test board was mounted on the test stage at Berkeley and 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.

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 1E4ion/cm2-s. to 4E5ion/cm2-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.

The AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (of the lot date code identified on the first page of this report) is susceptible to SEL events at various LETs as a function of case temperature. None of the events were observed to be destructive (i.e. all of the units-under-test continued to pass gross functionality following a power cycle), when using a current limit of 200mA and removing power within 10s from the beginning of the event. The following general results were obtained during the course of the testing:

1. The units pass SEL testing at a maximum LET of approximately 14.5MeV-cm^2/mg at an elevated case temperature of 125ºC, but failed at the next highest measured LET of 21MeV-cm^2/mg.
2. The units pass SEL testing at a maximum LET of approximately 21MeV-cm^2/mg at an elevated case temperature of 85ºC, but failed at the next highest measured LET of approximately 31MeV-cm^2/mg.
3. The units pass SEL testing at a maximum LET of approximately 31MeV-cm^2/mg at a case temperature of approximately 25ºC (ambient room temperature of Cave 4B at Berkeley National Laboratories), but failed at the next highest measured LET of approximately 59MeV-cm^2/mg

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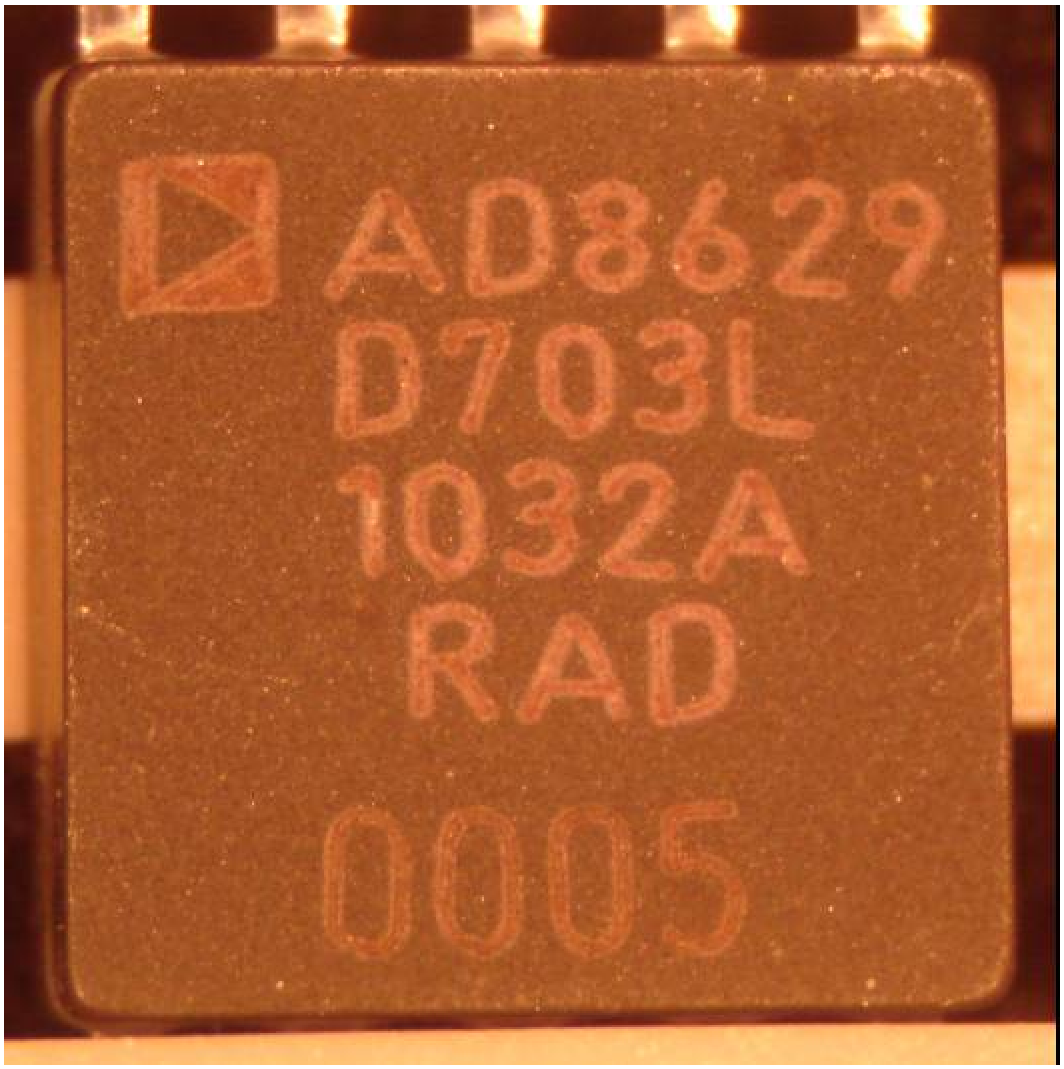
Appendix A: Photograph of a Sample Unit-Under-Test for Device Traceability and a Decapsulated Unit Ready for SEL Testing



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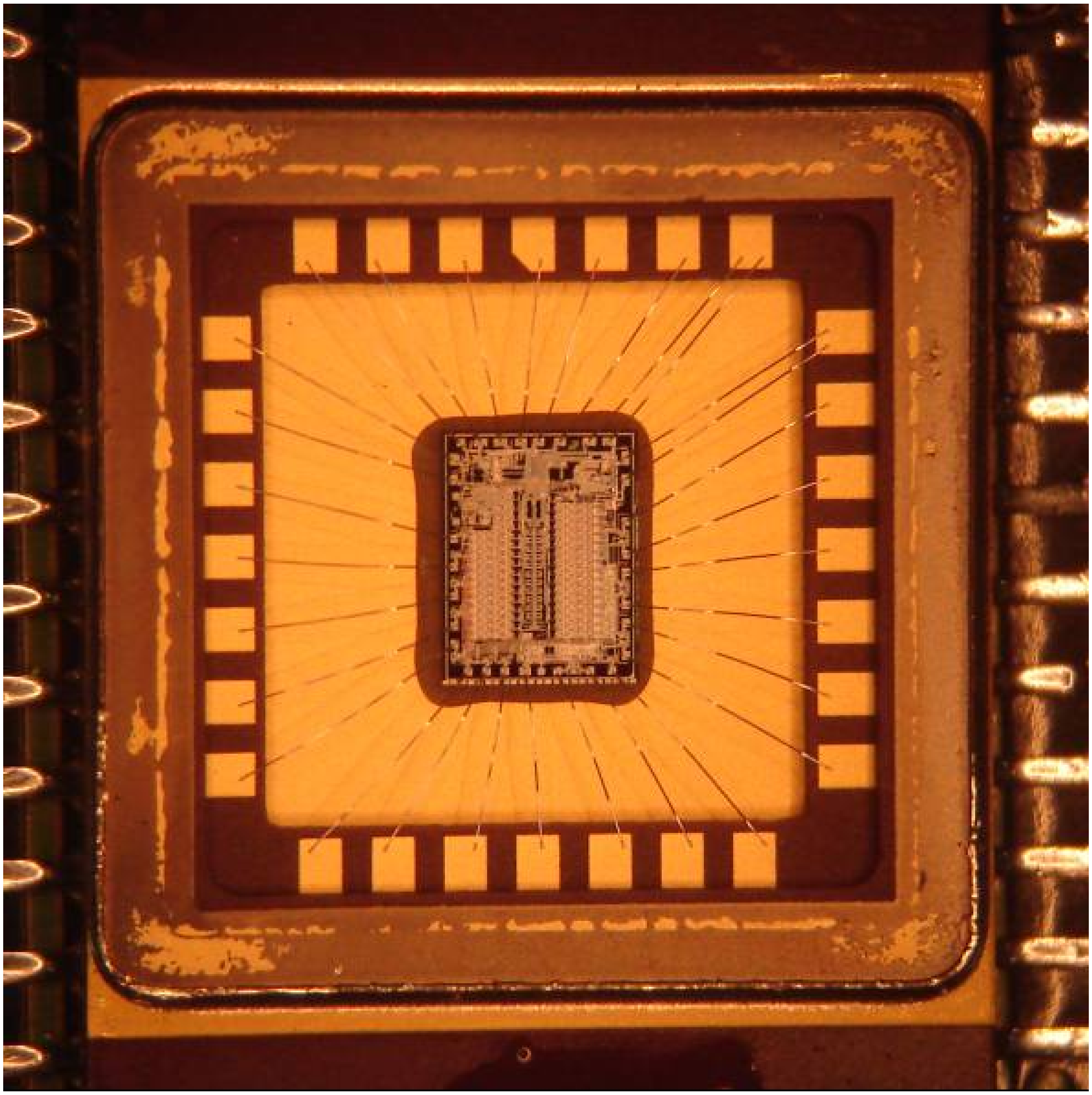

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Appendix B: Electrical Bias Conditions Used During Heavy Ion Exposure

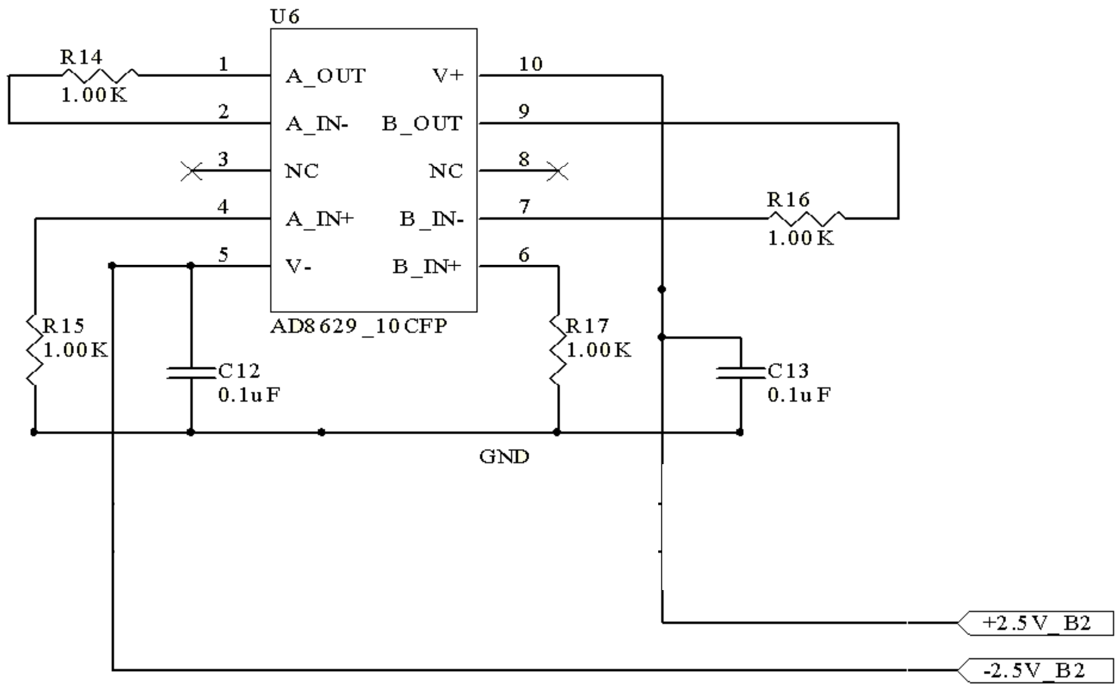

Figure B.1. Schematic drawing of the bias configuration used for the SEL test described in this final report.

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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. The AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier described in this final report was irradiated using the 10MeV/n Xe, Kr, Cu and Ar using a single ended supply voltage of 5V and at three case temperatures of 125°C, 85°C and 25°C (±5°C).

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 1E4ion/cm^2-s. to 4E5ion/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. Table C.1 shows the test equipment used for this testing.

Table C.1. Test equipment and calibration dates for testing the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier

HP 34401A Multimeter	3146A65284	5/15/011	5/15/12	Icc 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 TDS5104 Oscilloscope	B011044	10/22/10	10/22/11	Output Waveform Measurements