ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

SINGLE EVENT TRANSIENT 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

The RADTEST® DATA SERVICE is a compilation of radiation test results on Analog Devices' Space grade products. It is designed to assist customers in selecting the right product for applications where radiation is a consideration. Many products manufactured by Analog Devices, Inc. have been shown to be radiation tolerant to most tactical radiation environments. Analog Devices, Inc. does not make any claim to maintain or guarantee these levels of radiation tolerance without lot qualification test.

It is the responsibility of the Procuring Activity to screen products from Analog Devices, Inc. for compliance to Nuclear Hardness Critical Items (HCI) specifications.

Warning:

Analog Devices, Inc. does not recommend use of this data to qualify other product grades or process levels. Analog Devices, Inc. is not responsible and has no liability for any consequences, and all applicable Warranties are null and void if any Analog Devices product is modified in any way or used outside of normal environmental and operating conditions, including the parameters specified in the corresponding data sheet. Analog Devices, Inc. does not guarantee that wafer manufacturing is the same for all process levels.

SINGLE EVENT TRANSIENT TEST REPORT

PRODUCT:	AD8629D703L
DIE TYPE:	6498X
DATE CODE:	1032
CASE TEMPERATURE:	25°C, 85°C, 125°C
EFFECTIVE LET:	(9.74 – 58.78) MeV-cm^2/mg
AVERAGE FLUX:	(8.26E3 – 4.67E5) ion/cm^2/s
TOTAL EFFECTIVE FLUENCE:	(6.93E4 – 1.04E7) ion/cm^2
FACILITIES:	Lawrence Berkeley National Laboratories
TESTED:	August 31, 2011

The RADTEST[SM] DATA SERVICE is a compilation of radiation test results on Analog Devices' Space grade products. It is designed to assist customers in selecting the right product for applications where radiation is a consideration. Many products manufactured by Analog Devices, Inc. have been shown to be radiation tolerant to most tactical radiation environments. Analog Devices, Inc. does not make any claim to maintain or guarantee these levels of radiation tolerance without lot qualification test.

It is the responsibility of the Procuring Activity to screen products from Analog Devices, Inc. for compliance to Nuclear Hardness Critical Items (HCI) specifications.

WARNING:

Analog Devices, Inc. does not recommend use of this data to qualify other product grades or process levels. Analog Devices, Inc. is not responsible and has no liability for any consequences, and all applicable Warranties are null and void if any Analog product is modified in any way or used outside of normal environmental and operating conditions, including the parameters specified in the corresponding data sheet. Analog Devices, Inc. does not guarantee that wafer manufacturing is the same for all process levels.

ANALOG DEVICES

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Single Event Transient Testing of the AD8629 Zero Drift, Single-Supply, Rail-to-Rail 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).

Irradiation Temperature: 25°C to 125°C case temperature. The SET data was captured as part of an SET evaluation of this device.

The AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier exhibited SET events at various LETs. The SETs were manifested primarily as disruptions in the output level lasting up to approximately 10µs. The capture of SETs was limited due to single event latchups occurring in this device type.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

1.0. Overview and Background

It is well known that heavy ion exposure can cause soft errors (temporary events) that can spontaneously recover or require an external operation to restore. The errors can occur through various mechanisms including single event upset (SEU), single event functional interrupt (SEFI) and/or single event transient (SET). A SEU event occurs when a feedback storage element (typically a 6-transistor memory cell or D-type flip-flop) switches from one state to the other. That is a logical "1" flips to a logical "0" or vice versa. This new (and incorrect) state persists until the user rewrites the correct data into the storage element. A single event functional interrupt is similar to an SEU event in that a storage element switches state due to a single heavy ion. Where an SEU generally affects only a single bit of data within a word (and is usually correctable using error detection and correction (EDAC) a SEFI will cause the loss of proper functionality of the unit-under-test and will frequently require a power cycle to restore proper operation of the device.

An SET is an error that usually affects combinational logic cells instead of storage latches (as discussed above for SEUs and SEFIs). For SETs the heavy ion will cause a momentary disruption of an input or output of a particular cell within the unit-under-test that propagates through the internal logic paths and becomes manifested as a temporary disruption of the proper operation of the device. The two test standards usually used to govern this testing are ASTM F1192 and EIA/JESD57. This non-destructive single event effects testing is usually performed at the minimum datasheet voltage and at room temperature to a total fluence of 1E6ion/cm2 or until a "statistically significant" number of events are captured.

2.0. Single Event Transient Test Apparatus

The non-destructive single event effects testing described in this final report was performed at Lawrence Berkeley National Laboratories (LBNL) using their 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 single event transient testing performed at LBNL the devices were 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 was 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 took place. Table 2.1 shows the beam characteristics available at Berkeley.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

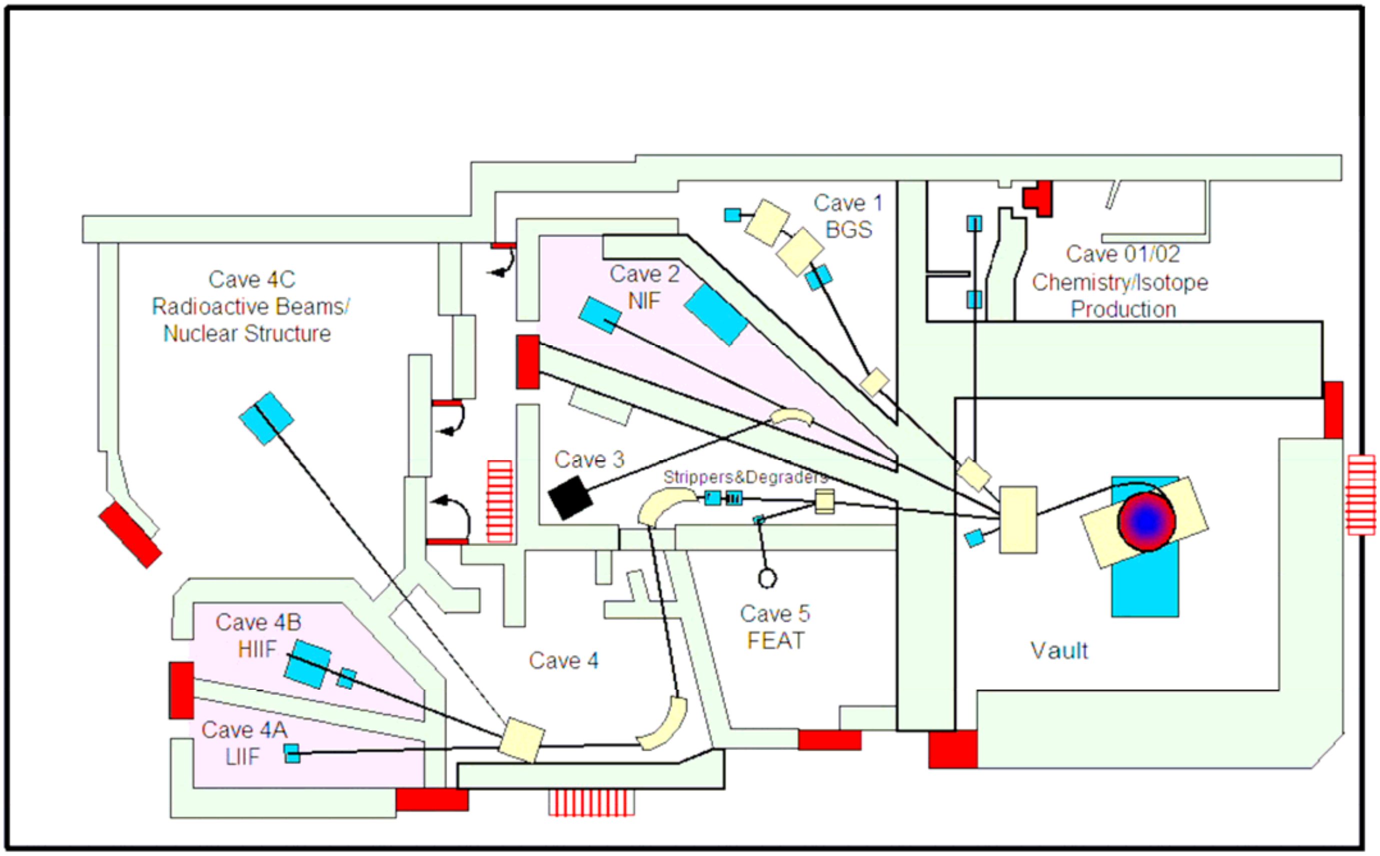


Figure 2.1. Map of 88-Inch Cyclotron Facility showing the location of Cave 4B, where the SEE testing was performed.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

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 SET 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 SETection 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. Note that these units exhibited single event latchup and the beam exposure was terminated shortly after the event was detected.

For the elevated temperature portion of the 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.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

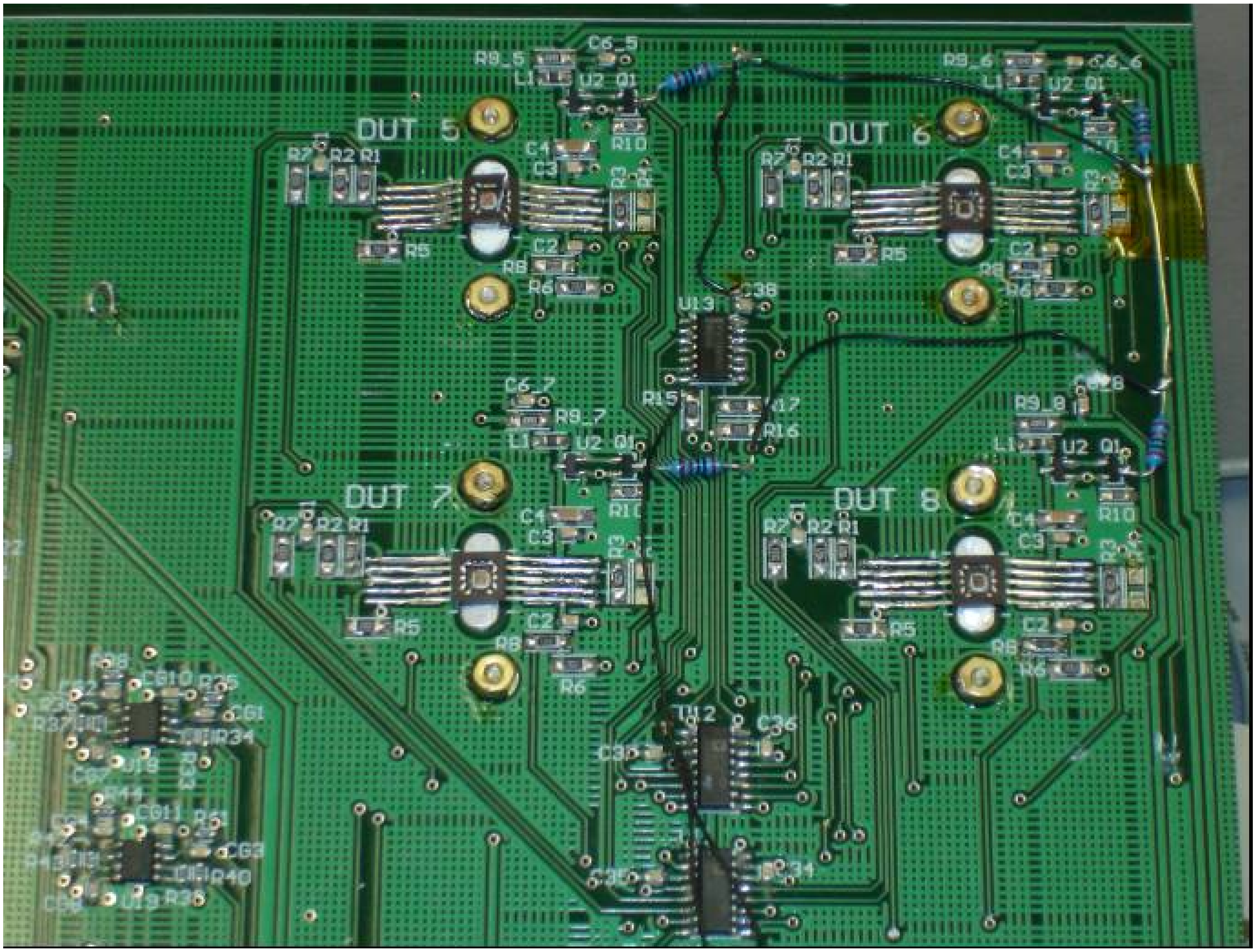


Figure 3.1. Single event test board that was mounted on the test stage at Berkeley. The board has four units-under-test (labeled as DUTs 5, 6, 7 and 8) mounted simultaneously to minimize vacuum breaks during testing. There is also a heater plate mounted to the backside of the board to provide the elevated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

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

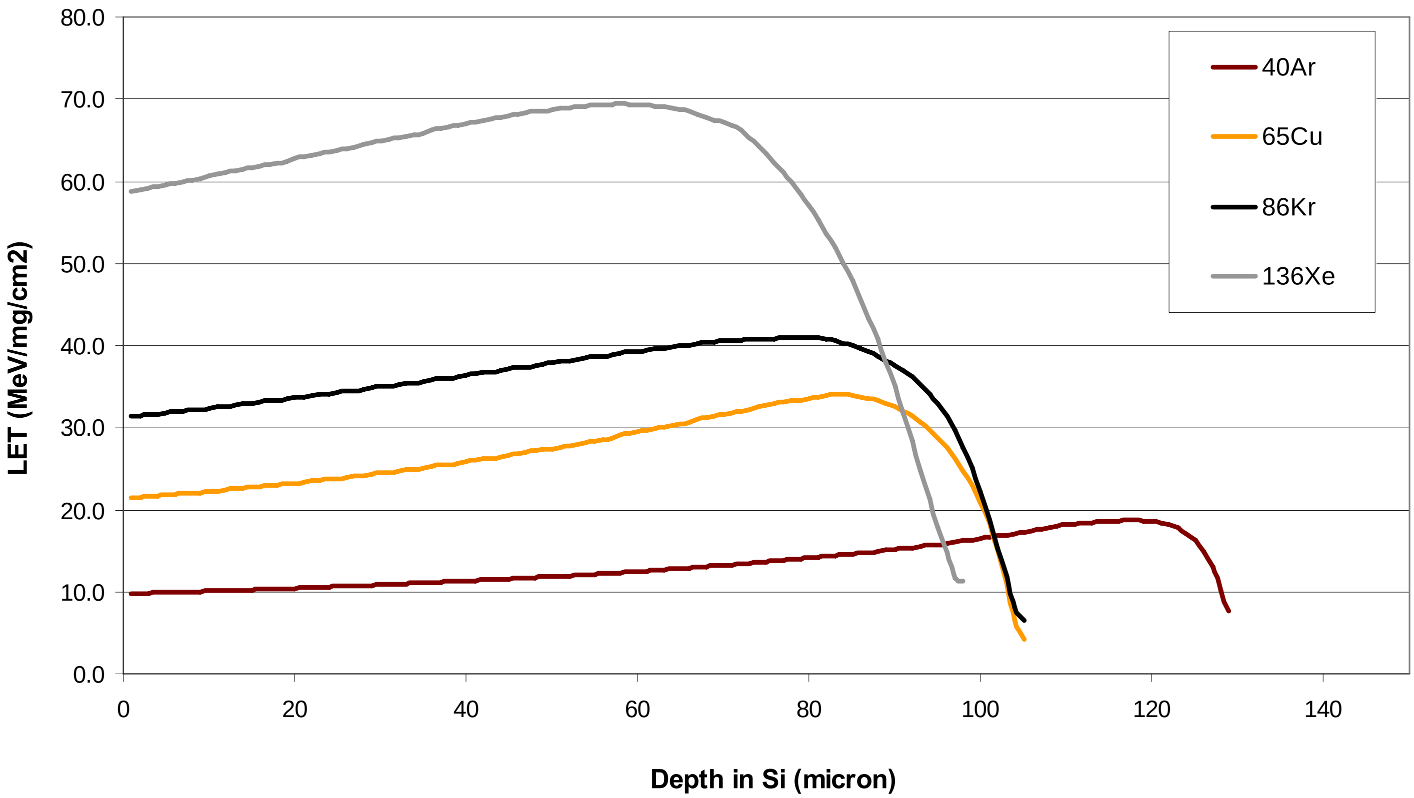


Figure 3.1. Range of the 10MeV/n Xe, Kr, Cu and Ar beams into silicon. The range to the Bragg Peak for Xe (the shortest range ion used) is approximately 60µm while the surface LET is approximately 58MeV-cm2/mg.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Ion	Cocktail (MeV/nuc)	Energy (MeV)	Z	A	Chg. State	% Nat. Abund.	LET 0° (MeV/(mg/cm^2))	LET 60° (MeV/(mg/cm^2))	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.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

4.0. Tested Parameters

During the heavy ion exposure the output of the units-under-test (for the device configured as non-inverting) was measured for proper operation. The units-under-test were run at statically and the output was captured on a digitizing oscilloscope (see Table C.1 for a list of the equipment used during this test) with the oscilloscope being triggered whenever there was a significant distortion in the output, either in amplitude or frequency. The output was configured for a nominal 400mV output and the trigger was set approximately 100mV above and below the output level. Note that for each test, the oscilloscope could run "indefinitely" in the acquisition/"ready for trigger" mode without triggering or capturing a waveform without application of the heavy ion beam. Therefore, we have a very high likelihood that after the unit-under-test was exposed to the heavy ion beam and an event occurs that the event was caused by the heavy ion radiation and not spurious noise.

During the heavy ion exposure the device was also monitored for single event latchup events, which would interfere with the operation of the unit-under-test and consequently the capture of SET events. The singe event latchup behavior of this device is reported separately in a report entitled "Single Event Latchup Testing of the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier for Analog Devices".

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 SET 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 SET 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 SET 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 SET (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 (minimum recommended operating voltage)
2. Set Stimuli voltages (mid-value)
3. Verify correct DUT output voltages

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

4. Configure scope to capture transients above and below noise floor (approximately 100mV above and below the nominal output level)
5. Turn ON ion beam, observe/monitor/log device current
6. Record scope data (waveforms, number of triggers, etc.)
7. Change ion flux as dictated (too many triggers/sec, too few)
8. Repeat process with different ion linear energy transfers (LETs)

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

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

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

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) are susceptible to SET events at various LETs. The SETs were manifested primarily as disruptions in the output level lasting approximately 10µs. As noted above and reported in a separate report ("Single Event Latchup Testing of the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier for Analog Devices") these units were susceptible to SEL events. The SEL events prohibited us from gathering a sufficient amount of statistical data, therefore the error-cross section for SETs is not reported here.

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 and comments regarding the test in the last column.

Figures 5.1 and 5.17 show plots of the SET events represented by output potential (configured as a non-inverting operational amplifier) versus time from the trigger event. As noted above the trigger was initiated if either the output waveform deviated in output potential by greater than or less than the widow trigger (approximately ±100mV). As seen in these figures, the SET events are manifested by a relatively minor perturbation in the output potential lasting for less than 10µs. In our opinion and depending on the use application, the SET events shown in this report should not cause significant effects at the system level or, if properly filtered go largely unnoticed.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Table 5.1. Summary of the SET test runs for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier

Run#	DUT	Temp (degC)	Total Eff Fluence	Average Flux	Ion	Eff LET	Angle	Comments
80	AD8629 dut8 sn12	25	3.16E+05	4.38E+04	Xe 58.78	58.78	0	Latched with 20 transients.
83	AD8629 dut6 sn3	25	1.02E+06	3.46E+04	Kr 30.86	30.86	0	20 Transient events no latch up
84	AD8629 dut5 sn2	25	1.02E+07	1.54E+05	Kr 30.86	30.86	0	SEL voltages 25C no latch
85	AD8629 dut5 sn2	90	3.04E+06	3.10E+05	Kr 30.86	30.86	0	90C latched
86	AD8629 dut5 sn2	85	1.03E+07	4.49E+05	Ar 9.74	9.74	0	85C no latch. Small transients.
88	AD8629 dut5 sn2	125	1.03E+07	4.67E+05	Ar 9.74	9.74	0	125C no latch w/ transients
89	AD8629 dut7 sn11	125	4.65E+06	4.08E+05	Ar 9.74	9.74	0	125C with no latchup
90	AD8629 dut7 sn11	125	1.04E+07	3.87E+05	Ar 9.74	9.74	0	no latch
91	AD8629 dut7 sn11	125	1.02E+07	3.90E+05	Ar 9.74	14.56	48	no latch
92	AD8629 dut5 sn2	125	1.02E+07	3.57E+05	Ar 9.74	14.56	48	no latch
93	AD8629 dut5 sn2	125	1.82E+05	9.35E+03	Cu 21.17	21.17	0	125C latched ~1.6e5
94	AD8629 dut5 sn2	125	2.65E+05	1.01E+04	Cu 21.17	21.17	0	125C latched ~2.5e5
95	AD8629 dut5 sn2	125	6.93E+04	9.69E+03	Cu 21.17	21.17	0	125C latched ~6e4
96	AD8629 dut5 sn2	125	4.79E+05	8.94E+03	Cu 21.17	21.17	0	125C latched 4.5e5
97	AD8629 dut6 sn3	85	1.01E+06	9.55E+03	Cu 21.17	21.17	0	85C no latch
98	AD8629 dut6 sn3	85	1.04E+06	1.01E+04	Cu 21.17	21.17	0	85C no latch
100	AD8629 dut8 sn12	85	1.01E+06	8.26E+03	Cu 21.17	21.17	0	85C no latch
101	AD8629 dut8 sn12	85	1.10E+06	1.54E+05	Kr 30.86	30.86	0	85C latched at 1e6
102	AD8629 dut8 sn12	85	1.95E+05	1.61E+04	Kr 30.86	30.86	0	85C latched at 2e5
103	AD8629 dut8 sn12	85	2.86E+05	3.77E+04	Kr 30.86	30.86	0	85C latched at 2e5
104	AD8629 dut8 sn12	125	1.65E+05	1.39E+04	Kr 30.86	30.86	0	125C latched 1.6e5
105	AD8629 dut8 sn12	125	1.19E+05	8.83E+03	Kr 30.86	30.86	0	125C latched 1.2e5
106	AD8629 dut7 sn11	85	7.66E+04	2.34E+04	Kr 30.86	30.86	0	85C latched 7.7e4
107	AD8629 dut7 sn11	85	3.81E+05	1.74E+04	Kr 30.86	30.86	0	85C latched at 3.8e5

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

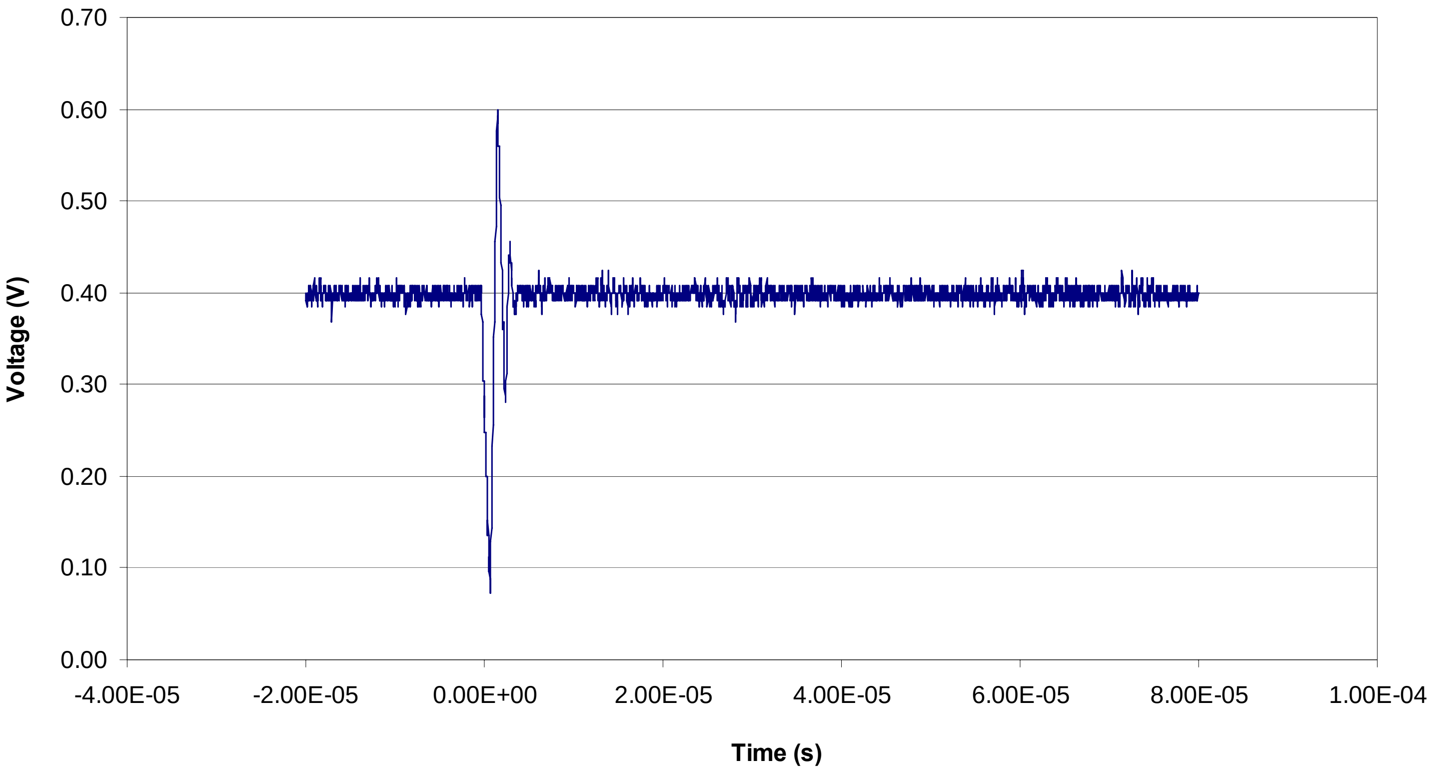


Figure 5.1. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 80, DUT 8, SN12). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

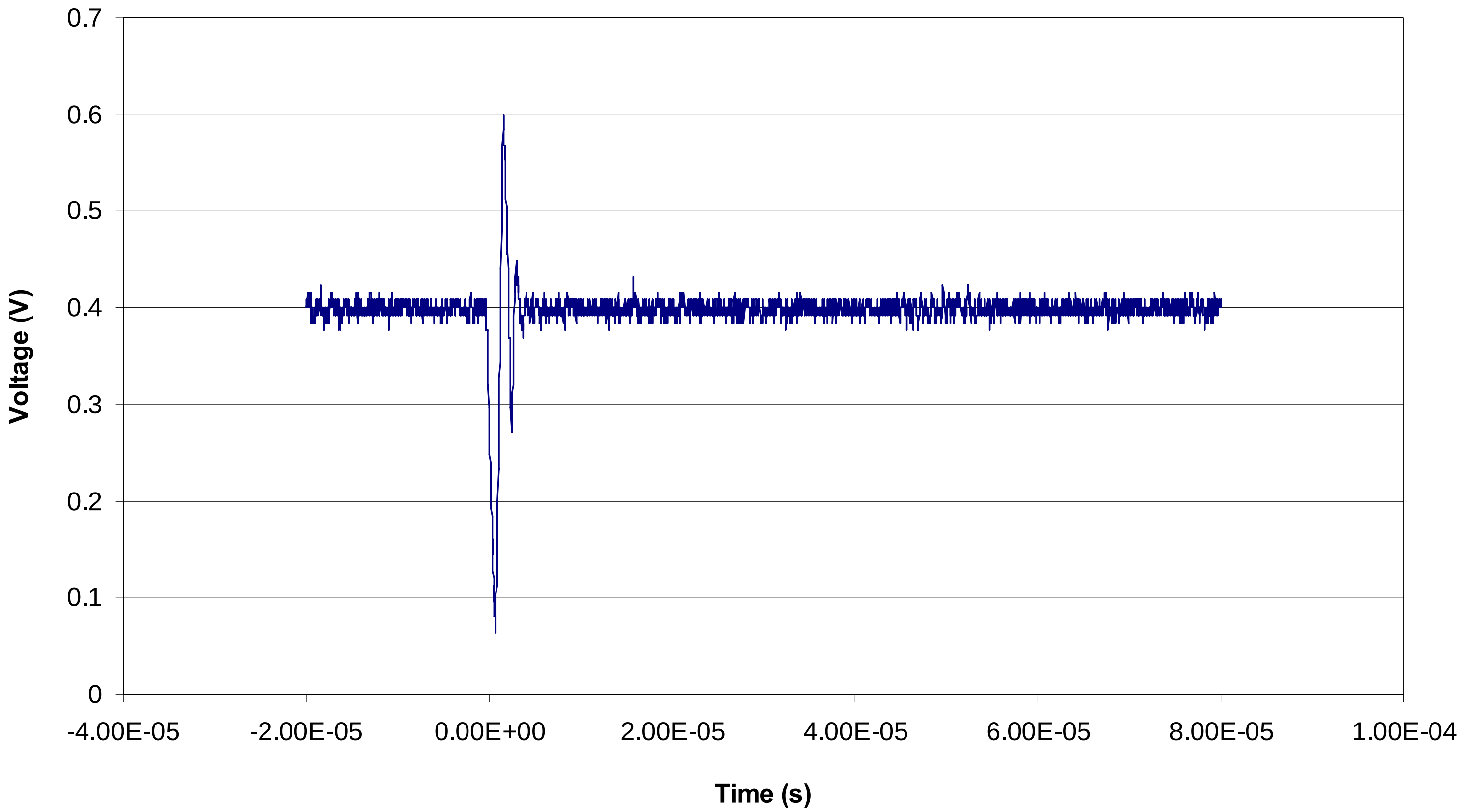


Figure 5.2. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 83, DUT 6, SN3). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

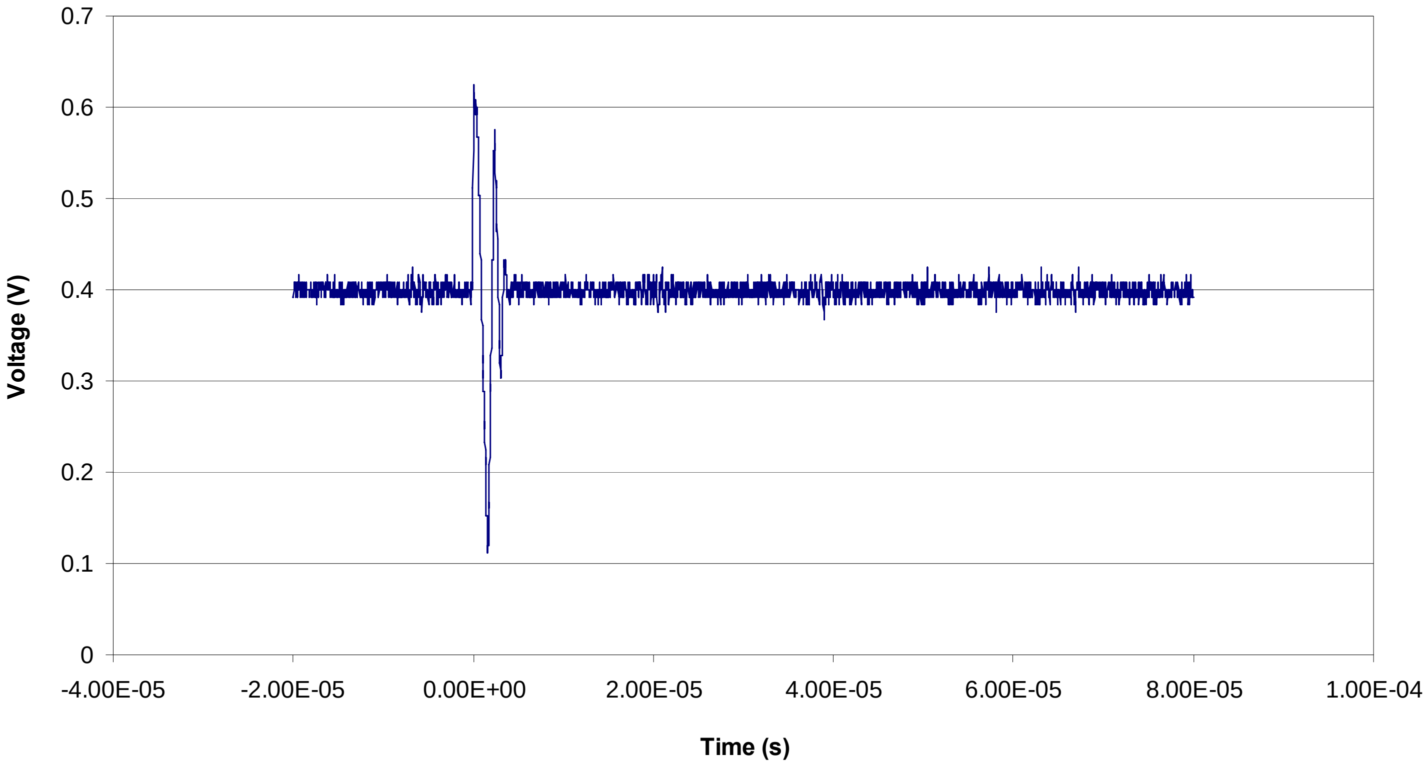


Figure 5.3. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 84, DUT 5, SN2). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

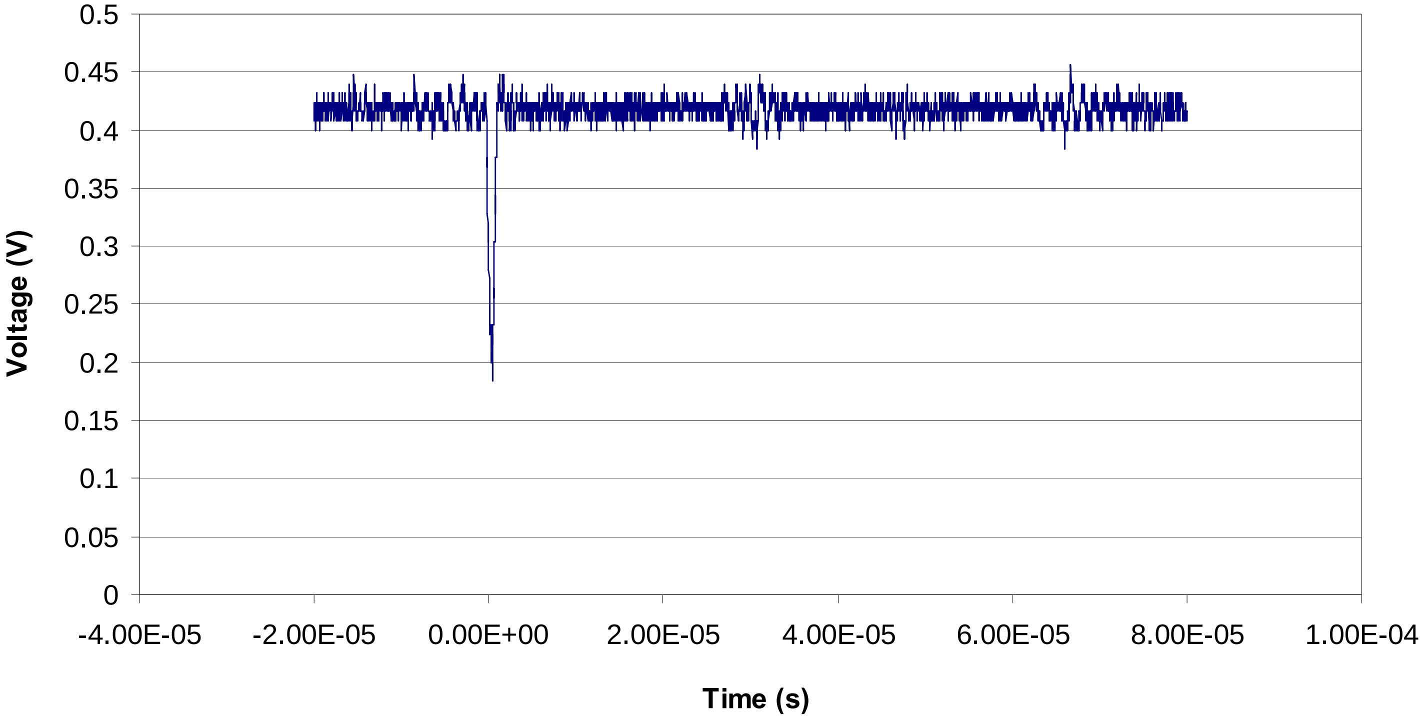


Figure 5.4. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 85, DUT 5, SN2). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

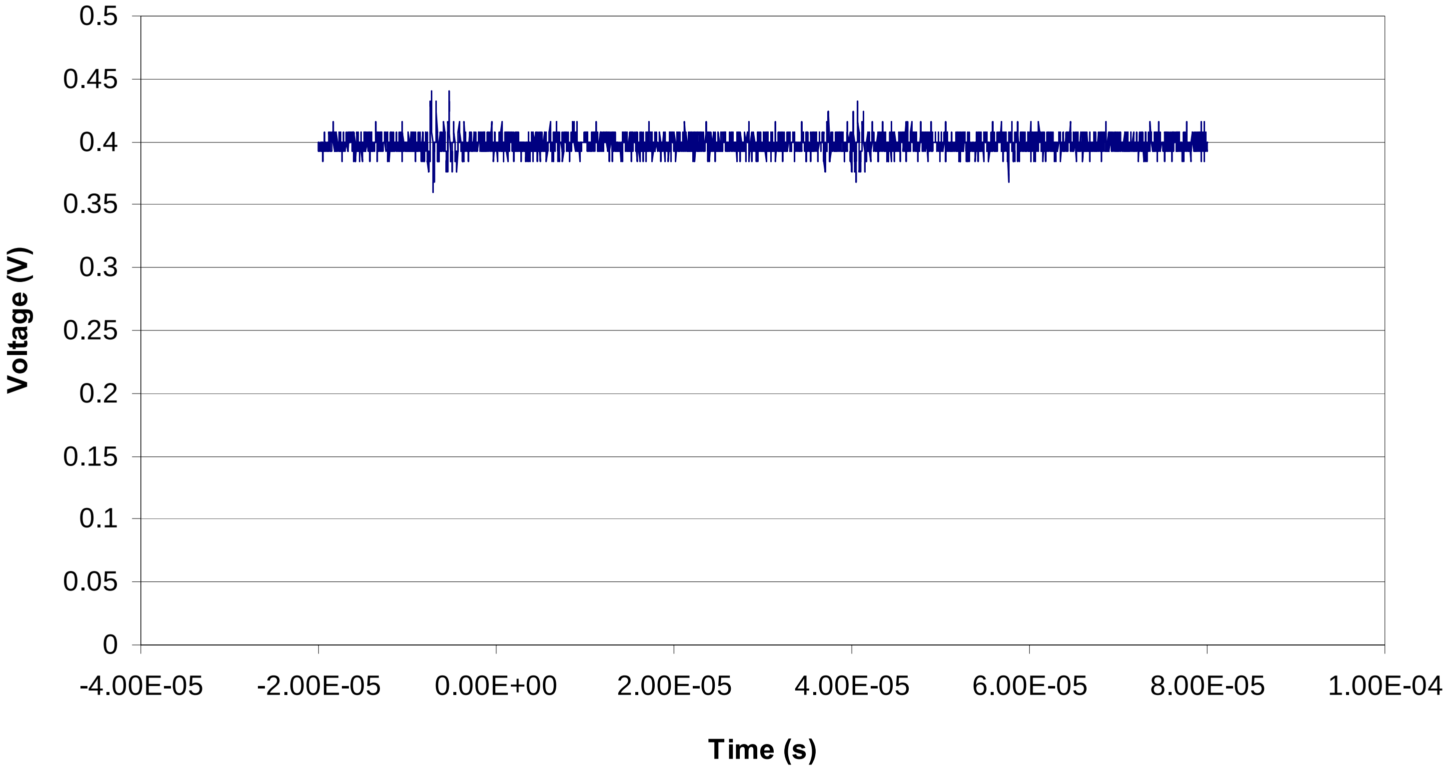


Figure 5.5. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 86, DUT 5, SN2). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

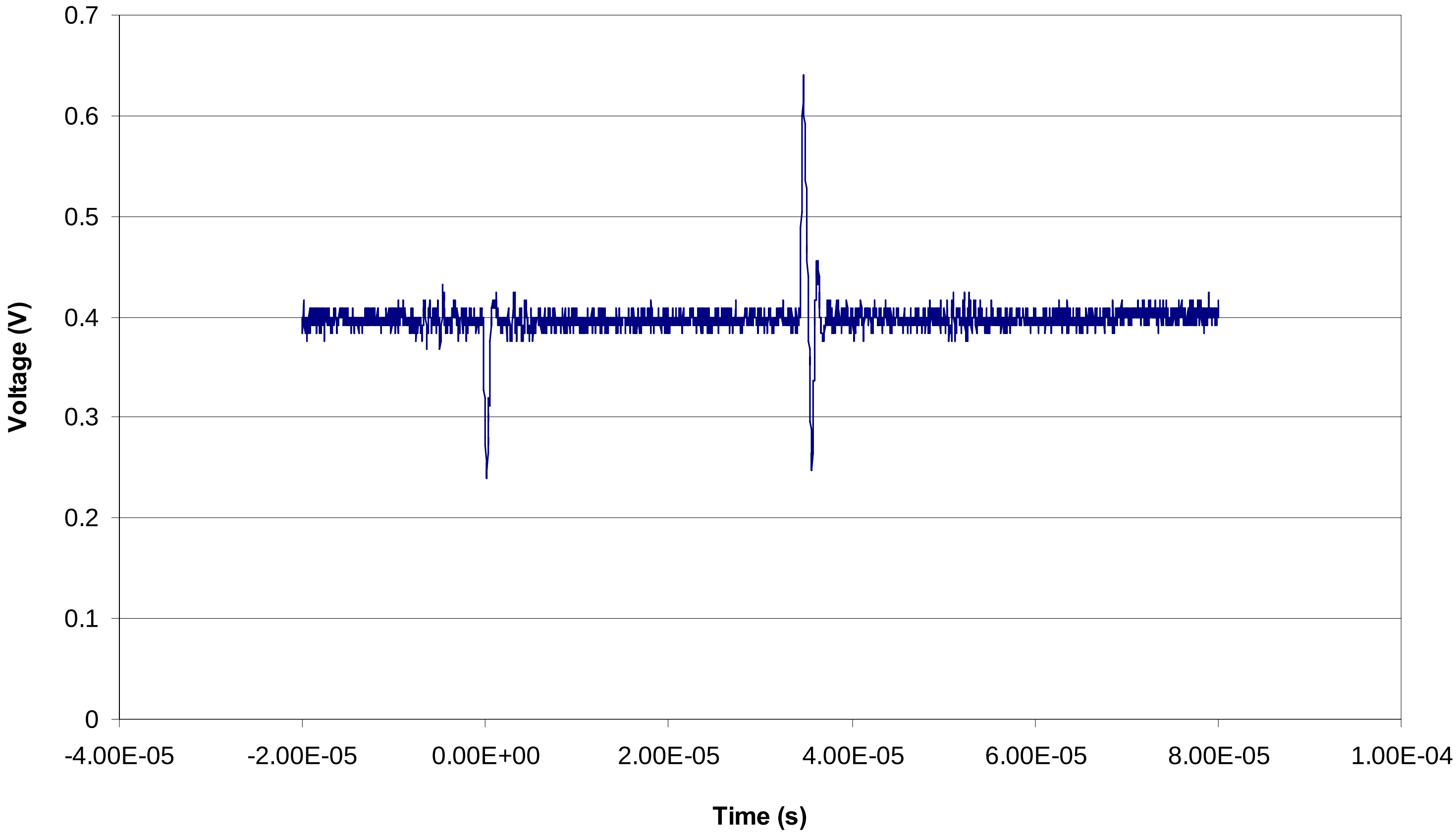


Figure 5.6. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 88, DUT 5, SN2). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

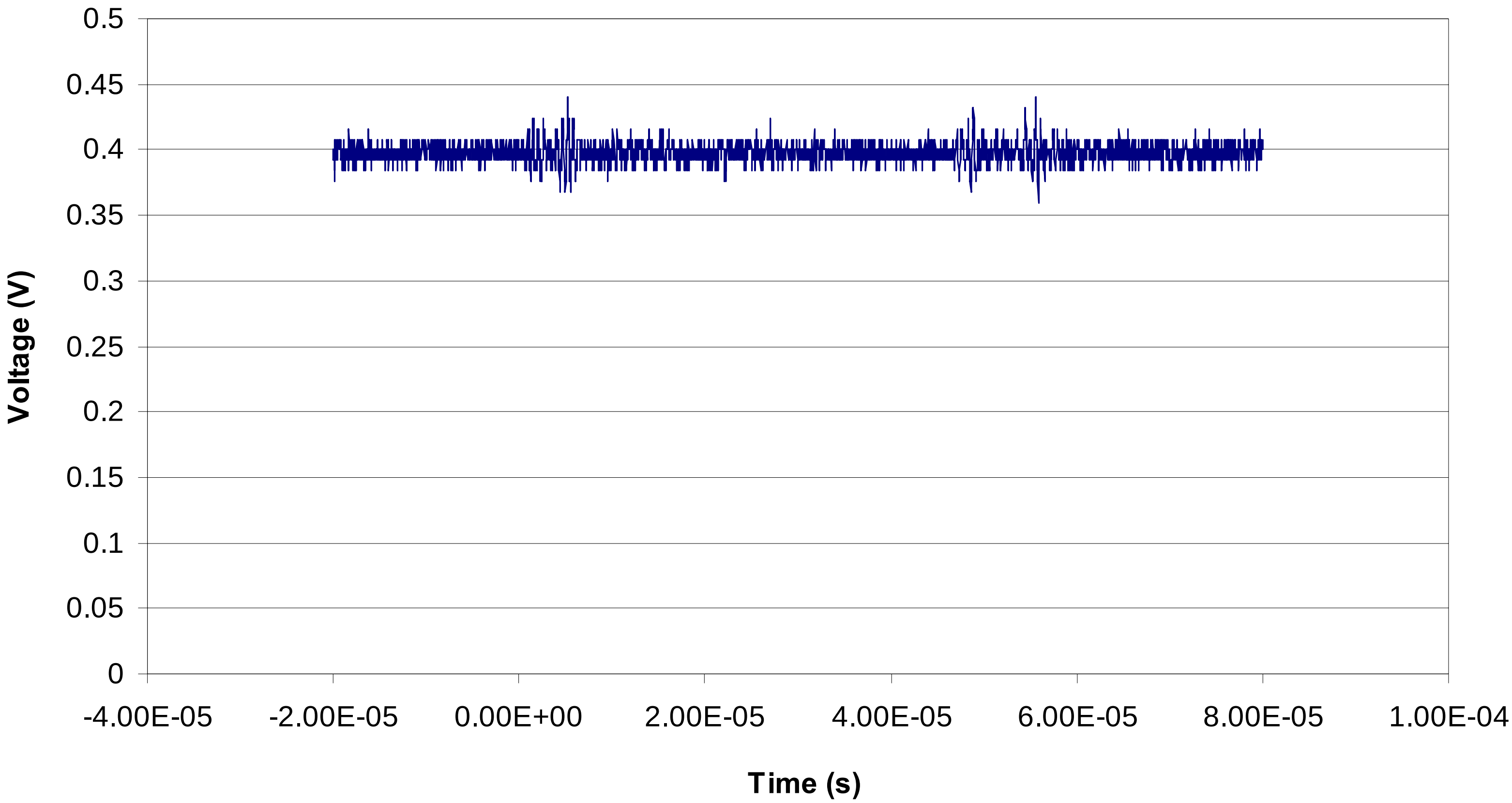


Figure 5.7. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 89, DUT 7, SN11). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

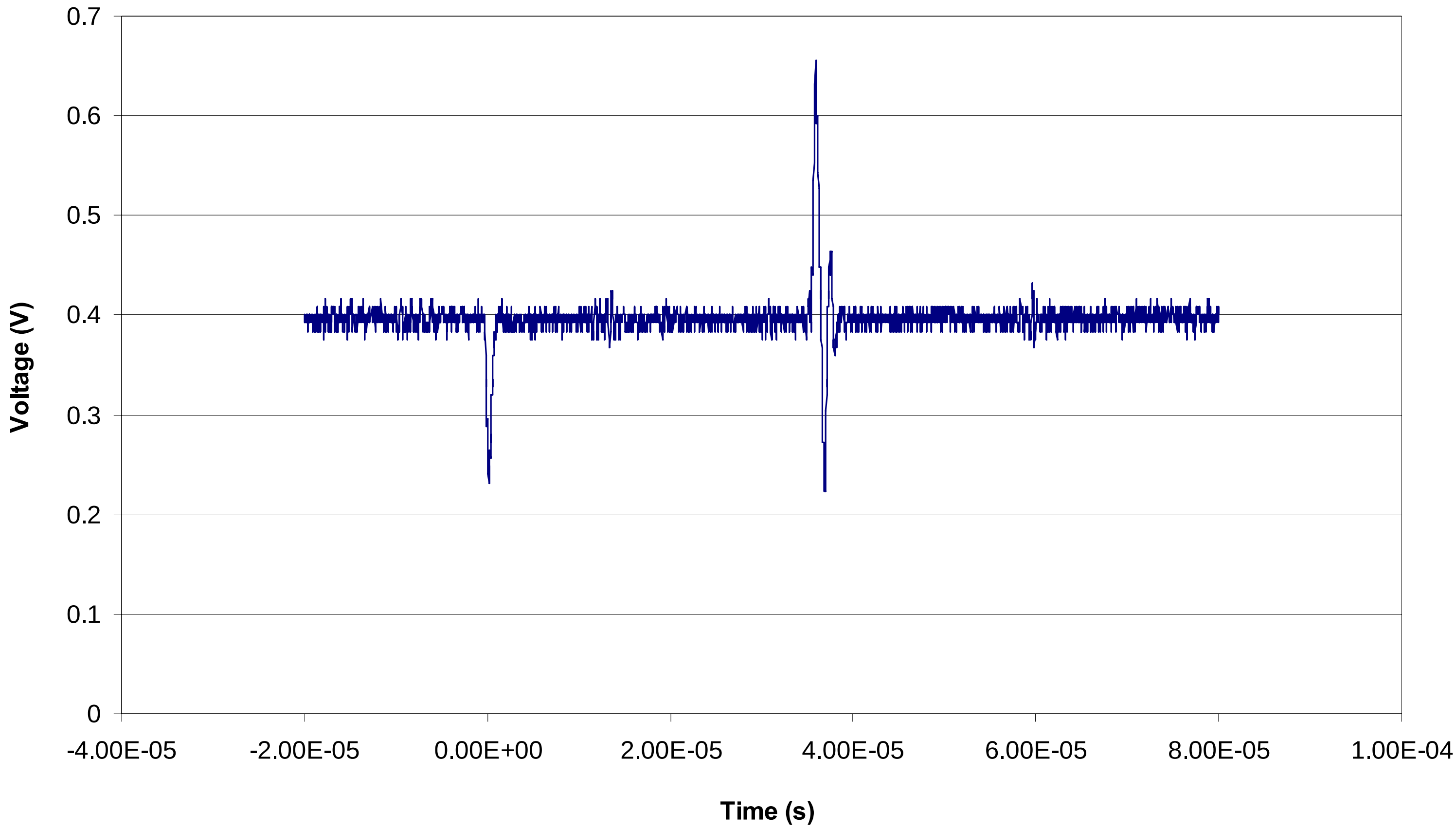


Figure 5.8. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 90, DUT 7, SN11). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

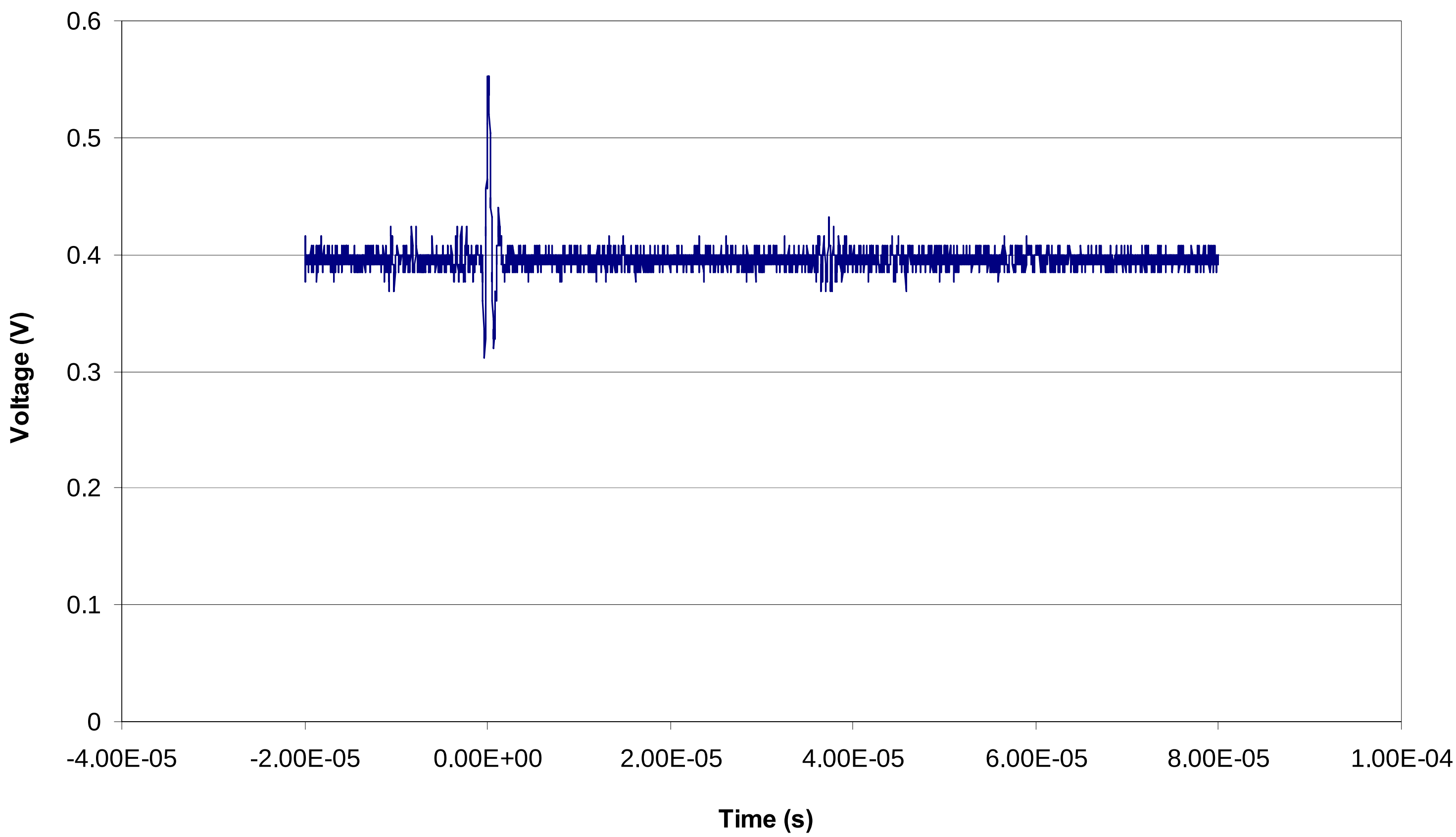


Figure 5.9. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 91, DUT 7, SN11). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

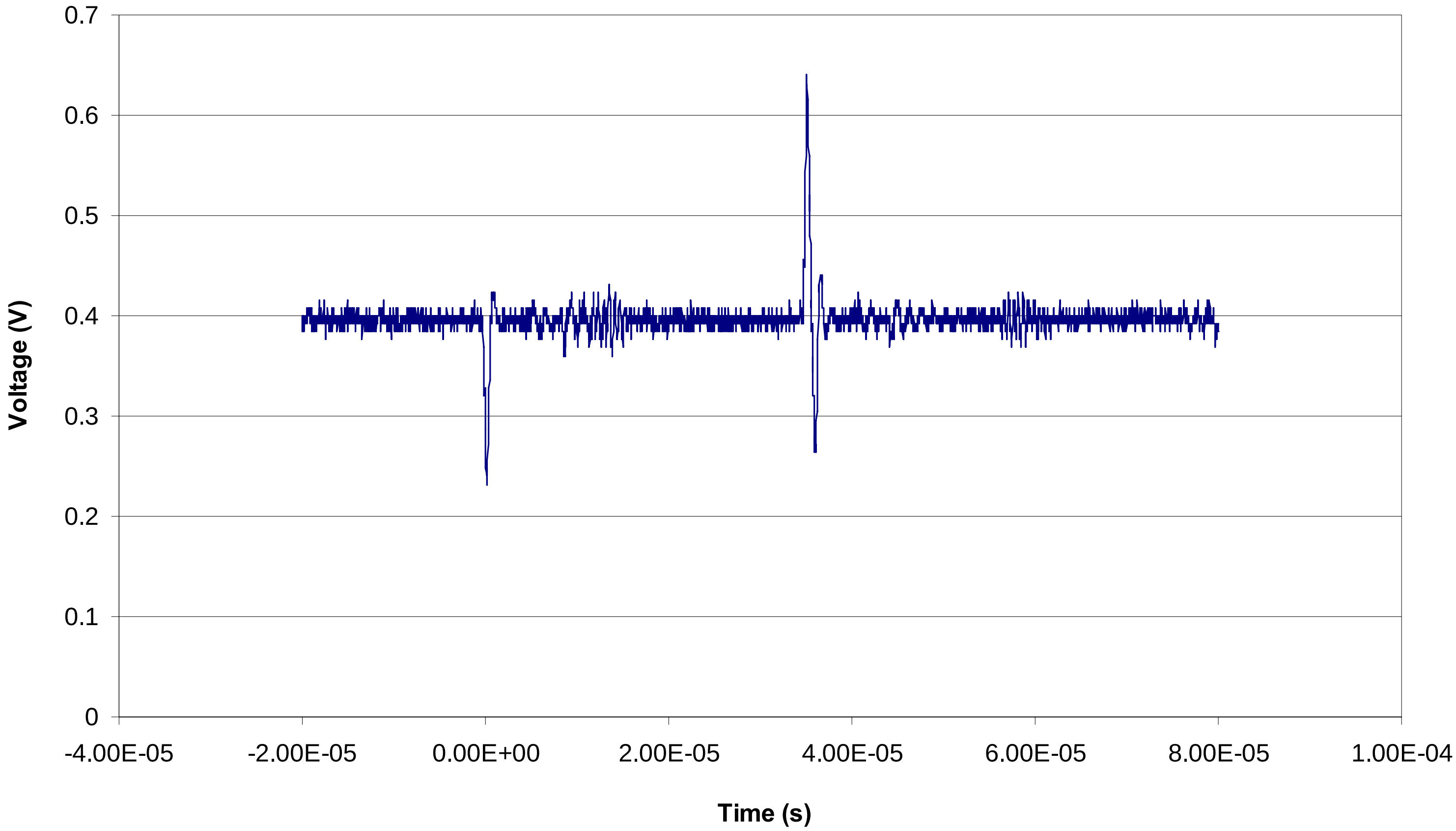


Figure 5.10. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 92, DUT 5, SN2). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

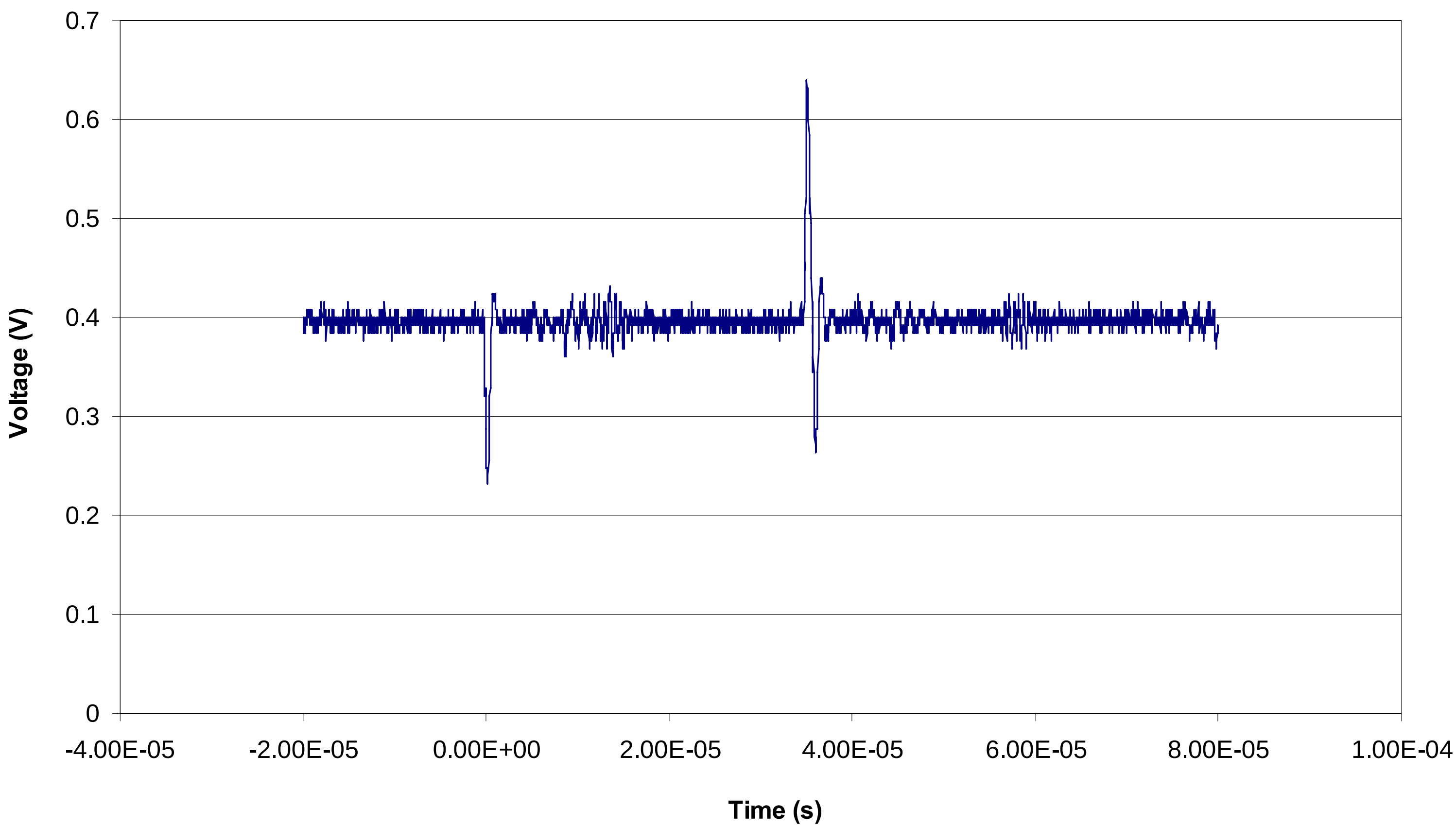


Figure 5.11. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 93, DUT 5, SN2). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

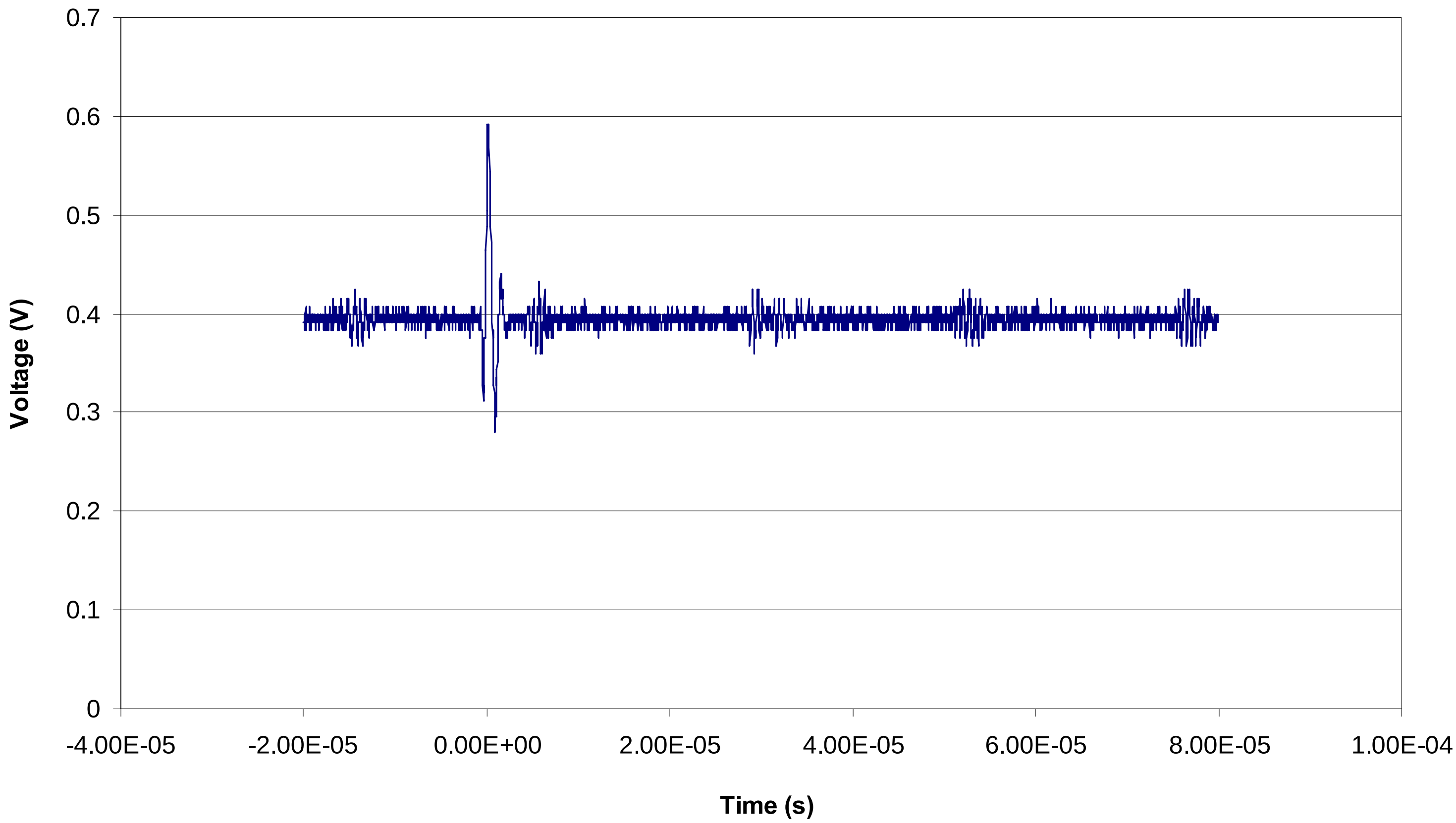


Figure 5.12. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 94, DUT 5, SN2). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

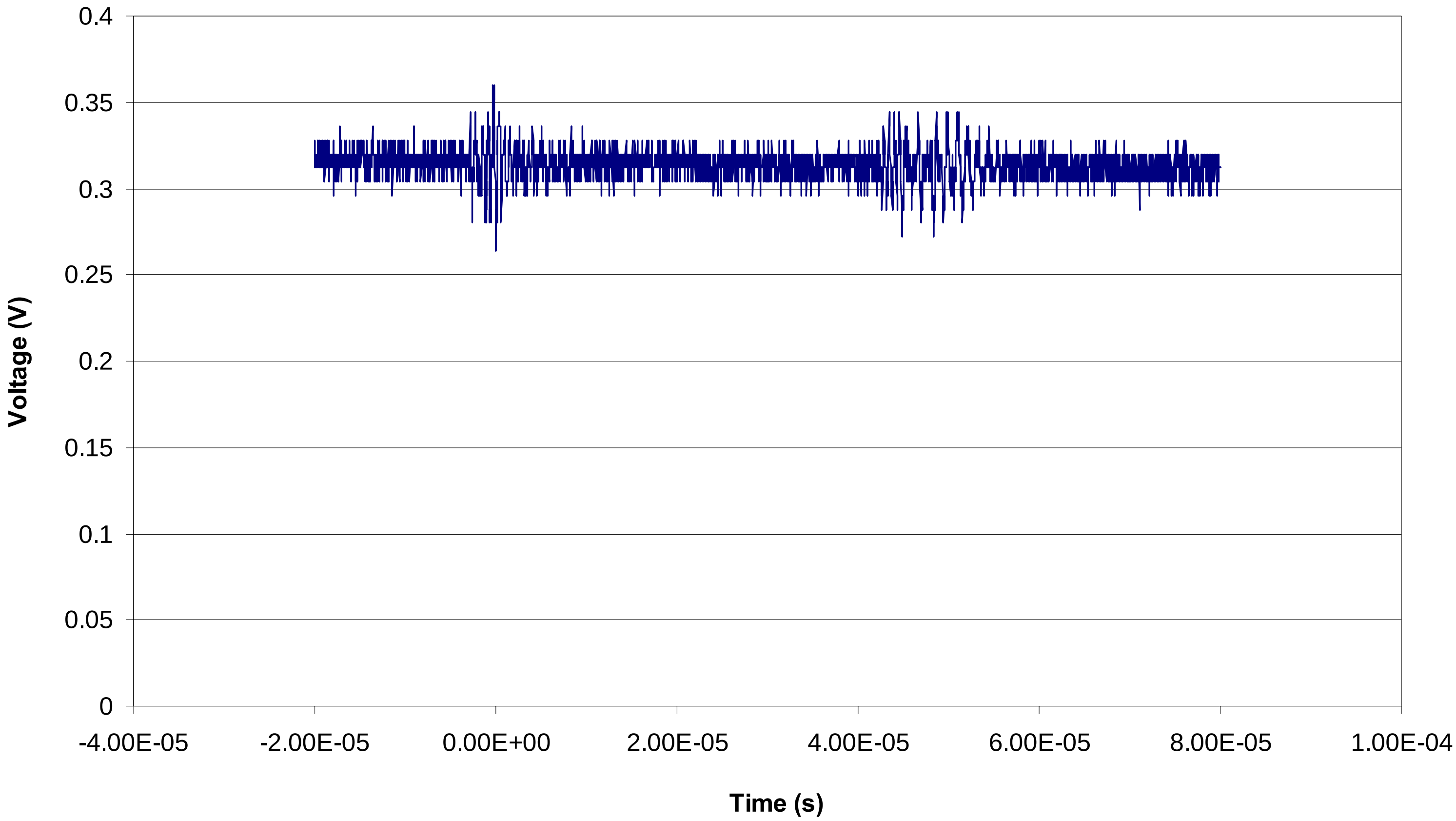


Figure 5.13. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 95, DUT 5, SN2). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

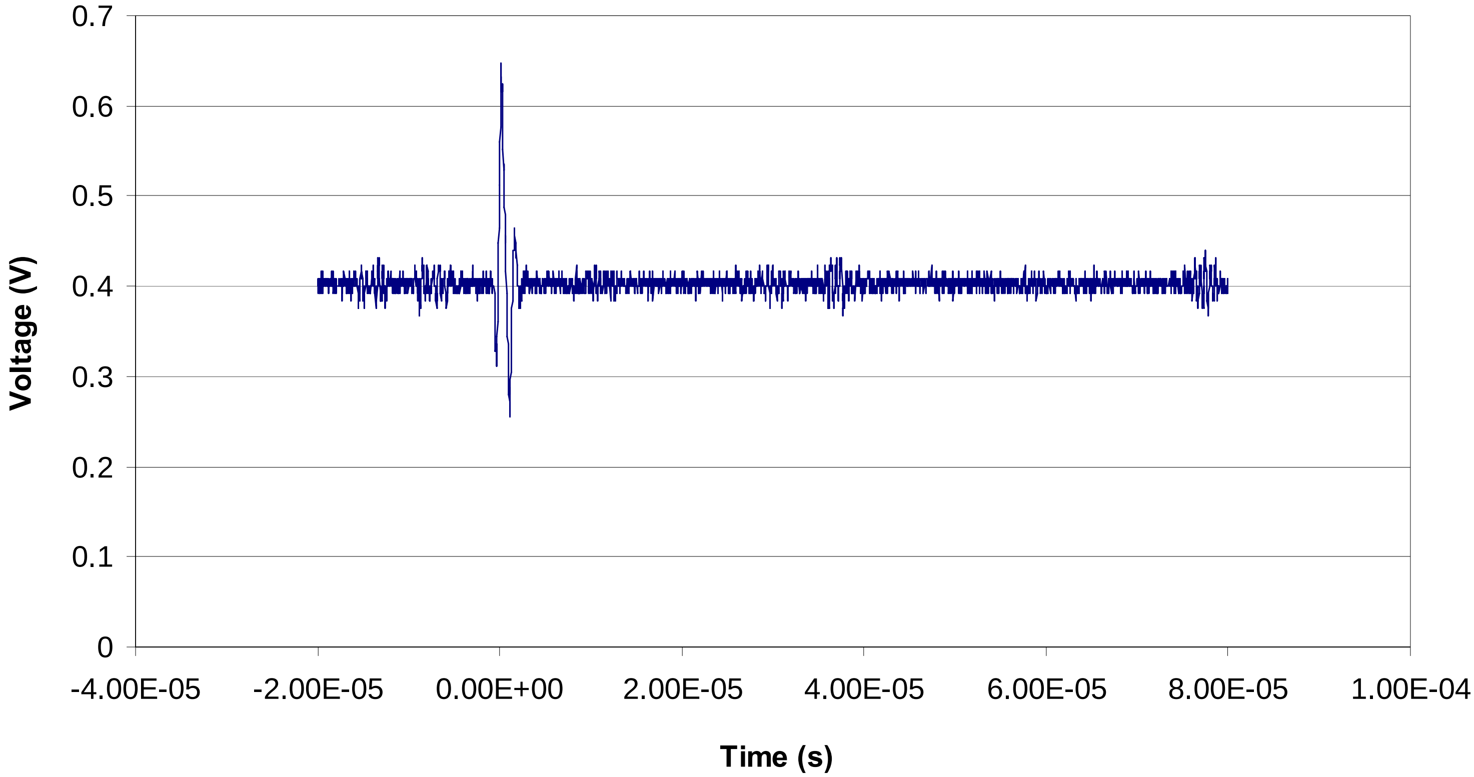


Figure 5.14. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 100, DUT 8, SN12). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

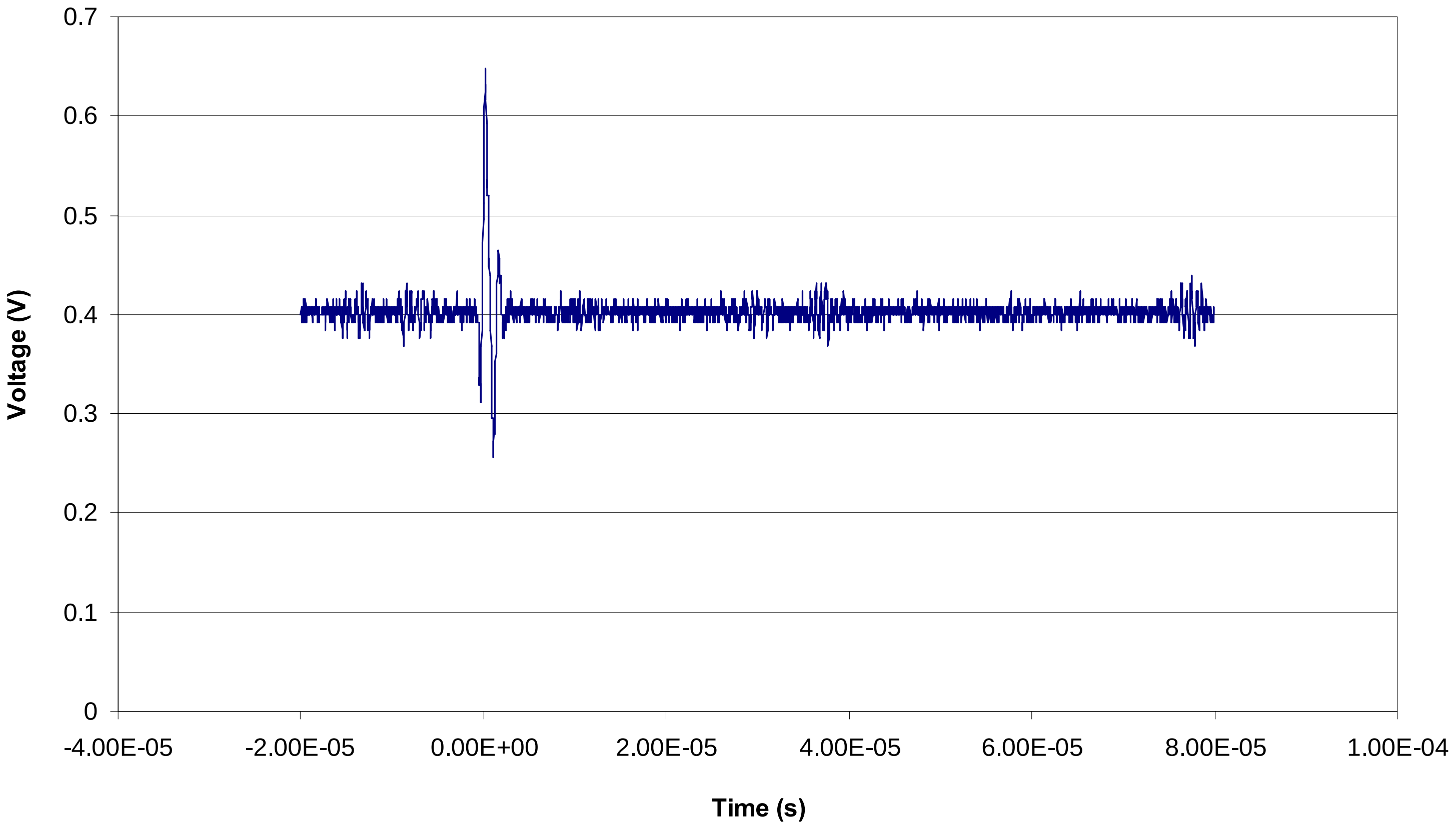


Figure 5.15. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 101, DUT 8, SN12). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

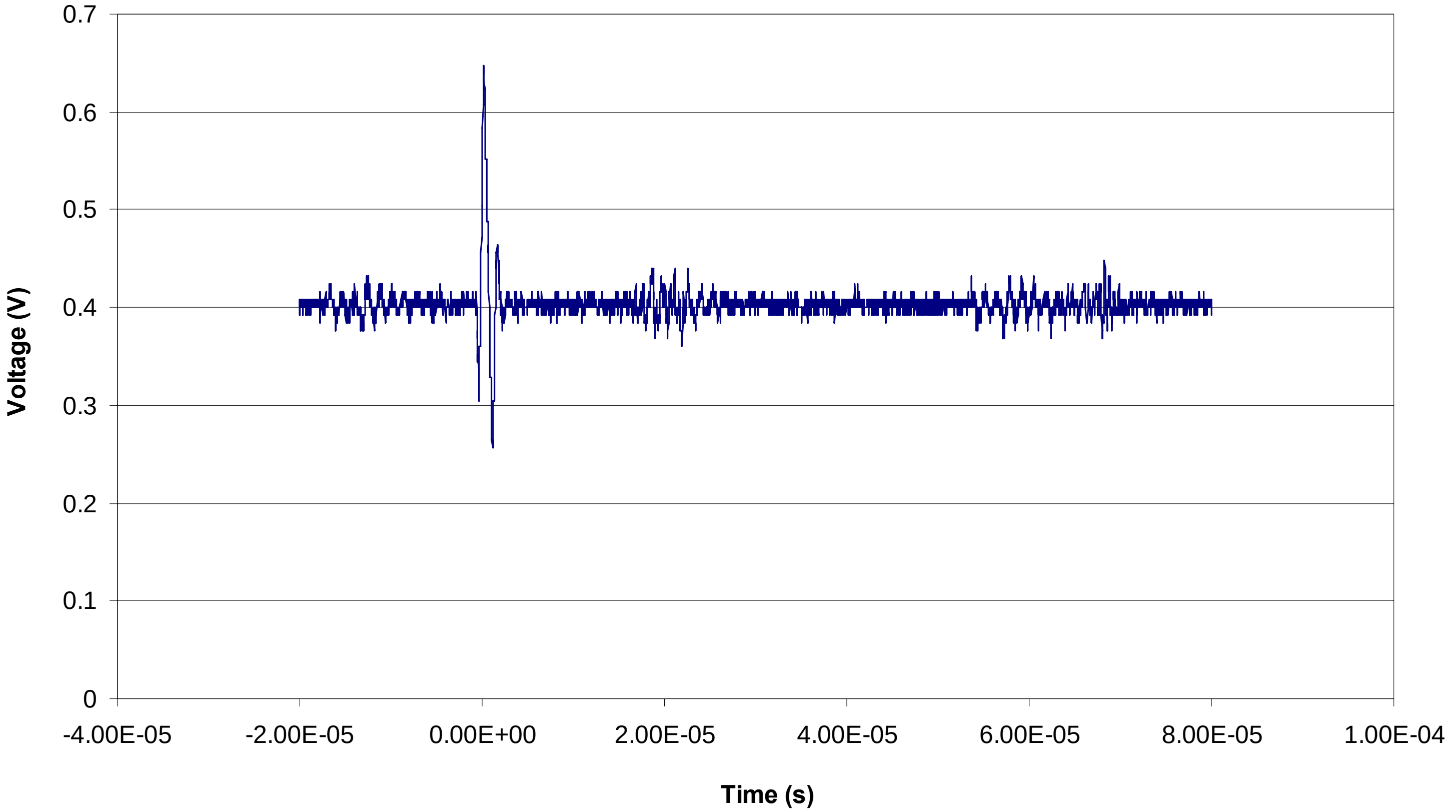


Figure 5.16. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 102, DUT 8, SN12). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

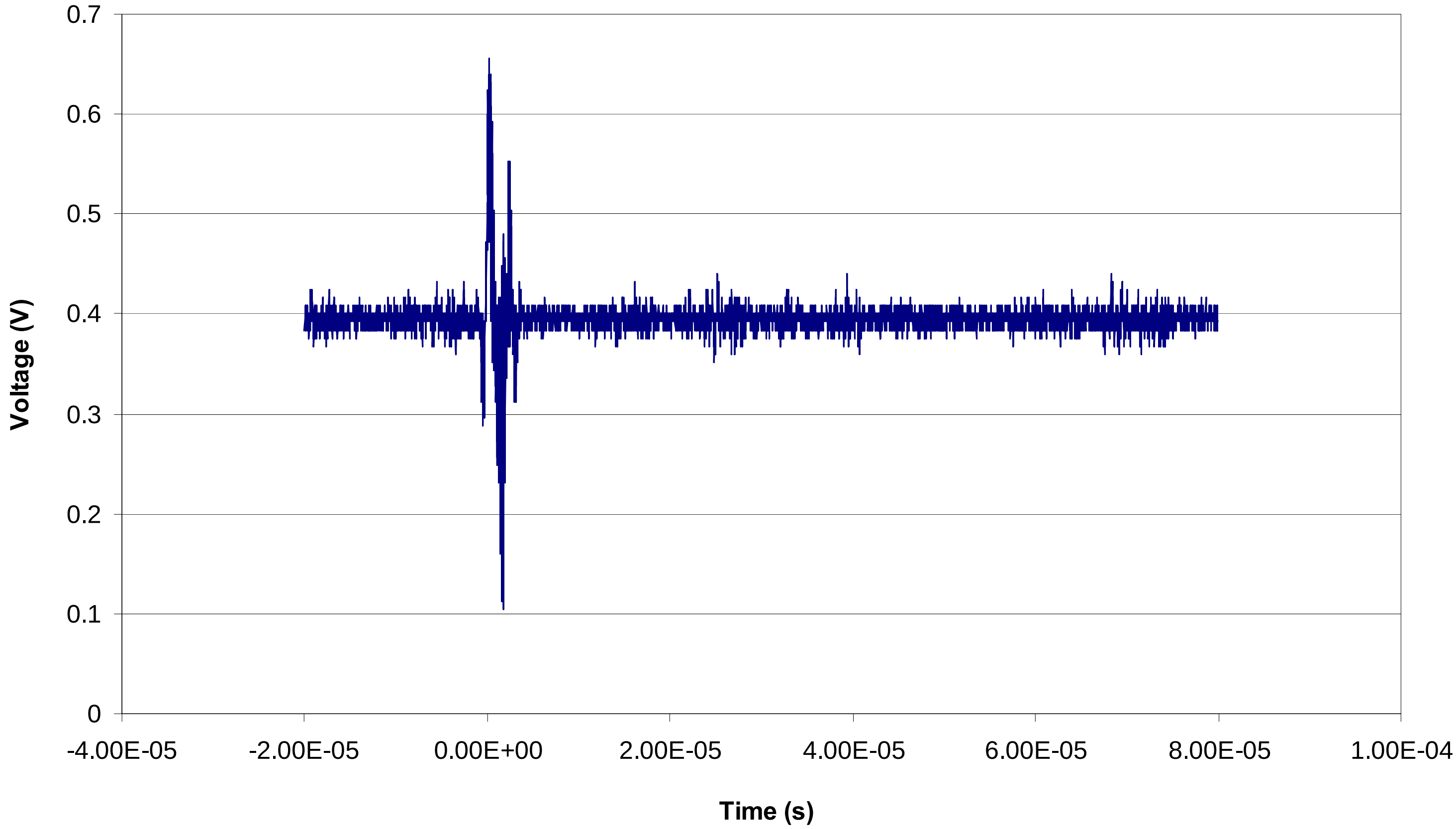


Figure 5.17. Representative single event transient for the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier (run 107, DUT 7, SN11). The data is presented as output potential versus time/fluence. In this figure the dark blue data points represent the output from the operational amplifier configured in the non-inverting mode. See Table 4.1 for the details of the test conditions.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

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.

During the heavy ion exposure the output of the units-under-test (for the device configured as non-inverting) was measured for proper operation. The units-under-test were run at statically and the output was captured on a digitizing oscilloscope with the oscilloscope being triggered whenever there was a significant distortion in the output, either in amplitude or frequency. The output was configured for a nominal 400mV output and the trigger was set approximately 100mV above and below the output level. Note that for each test, the oscilloscope could run "indefinitely" in the acquisition/"ready for trigger" mode without triggering or capturing a waveform without application of the heavy ion beam. Therefore, we have a very high likelihood that after the unit-under-test was exposed to the heavy ion beam and an event occurs that the event was caused by the heavy ion radiation and not spurious noise.

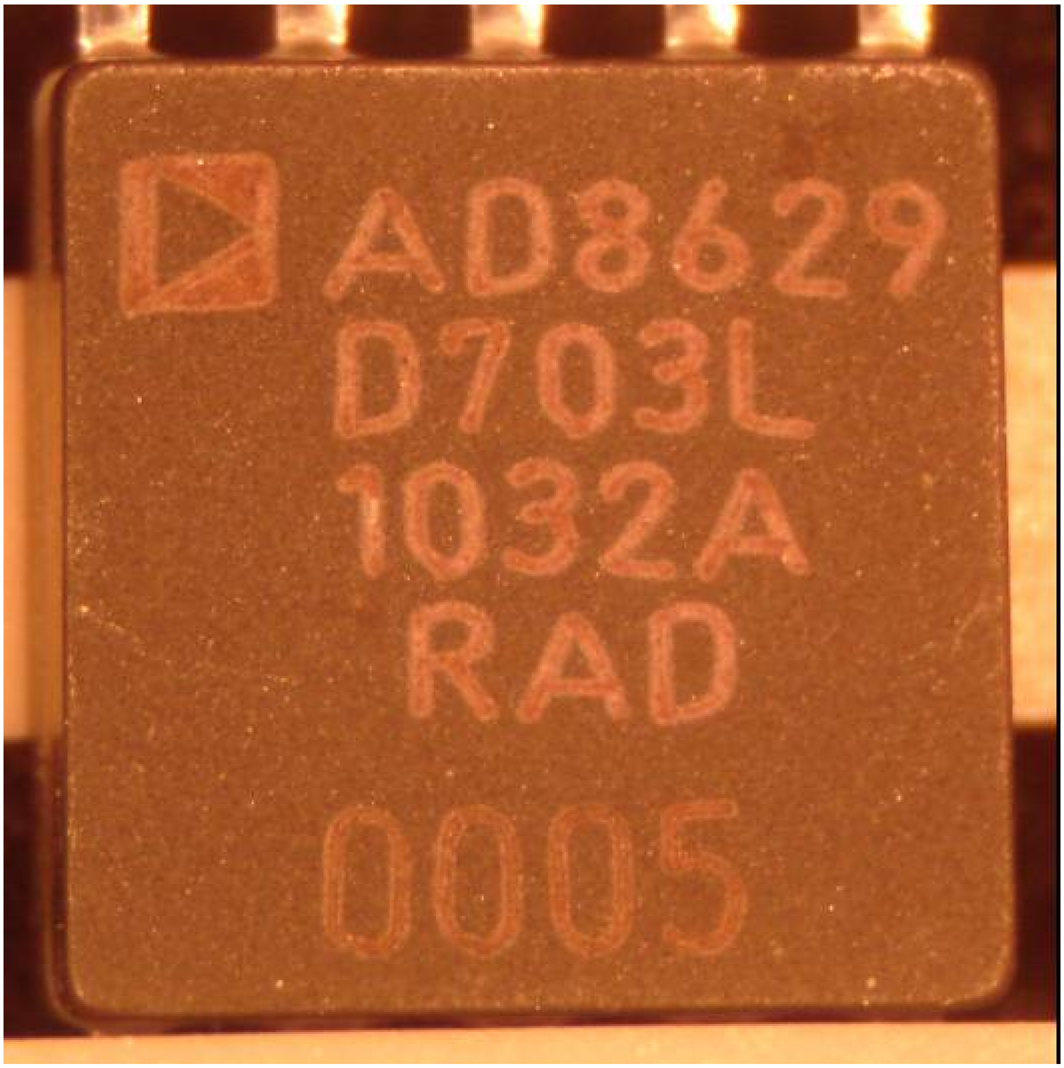
During the heavy ion exposure the device was also monitored for single event latchup events, which would interfere with the operation of the unit-under-test and consequently the capture of SET events. The singe event latchup behavior of this device is reported separately in a report entitled "Single Event Latchup Testing of the AD8629 Zero Drift, Single-Supply, Rail-to-Rail, Input/Output Operational Amplifier for Analog Devices".

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) are susceptible to SET events at various LETs. The SETs were manifested primarily as disruptions in the output level lasting approximately 10µs. These units were susceptible to SEL events and the SEL behavior prohibited us from gathering a sufficient amount of statistical data, therefore the error-cross section for SETs is not reported in this final report.

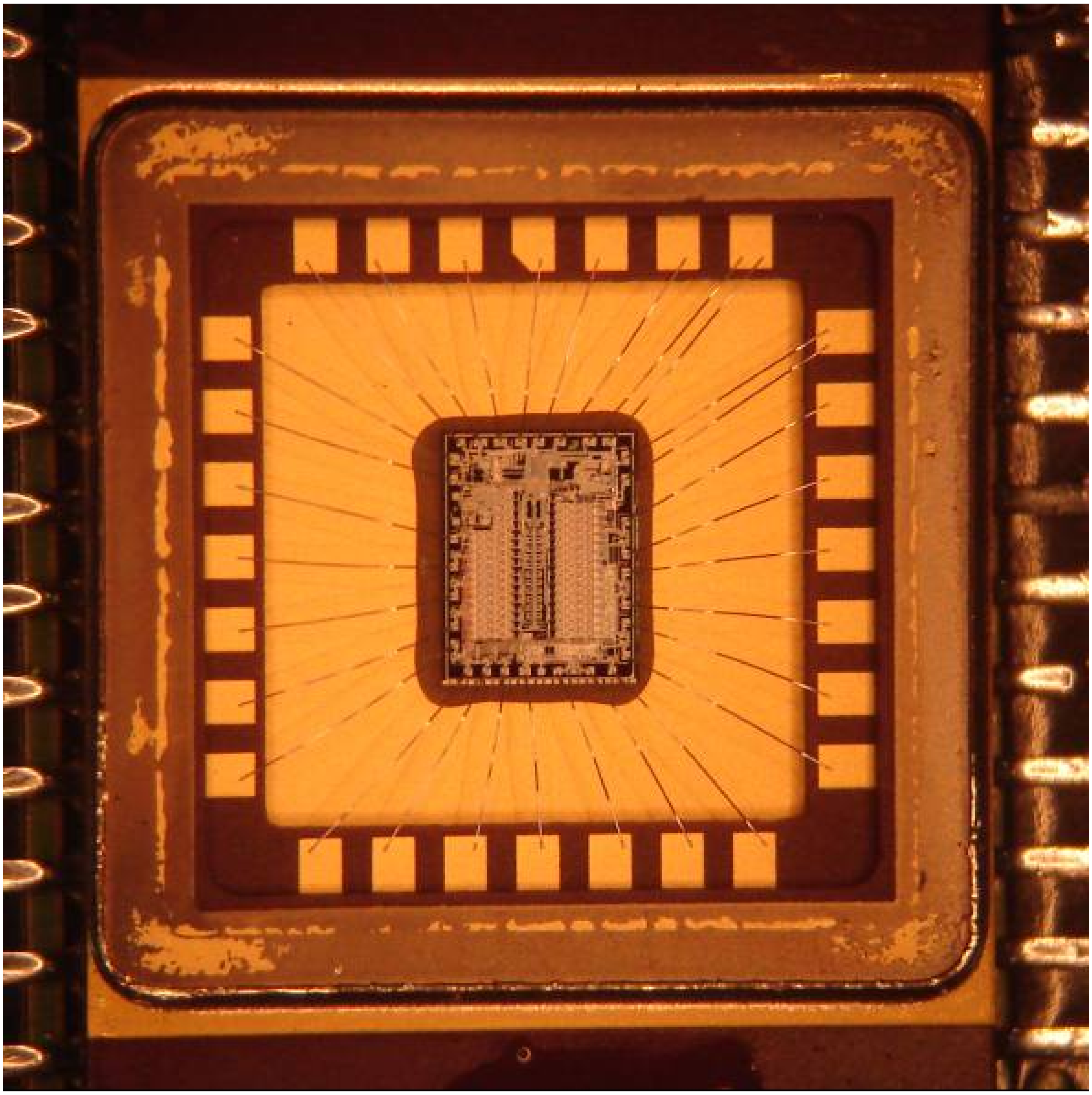
The SET events are manifested by a relatively minor perturbation in the output potential lasting for less than 10µs. In our opinion and depending on the use application, the SET events shown in this report should not cause significant effects at the system level or, if properly filtered go largely unnoticed.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

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



Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800



Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

Appendix B: Electrical Bias Conditions Used During Heavy Ion Exposure

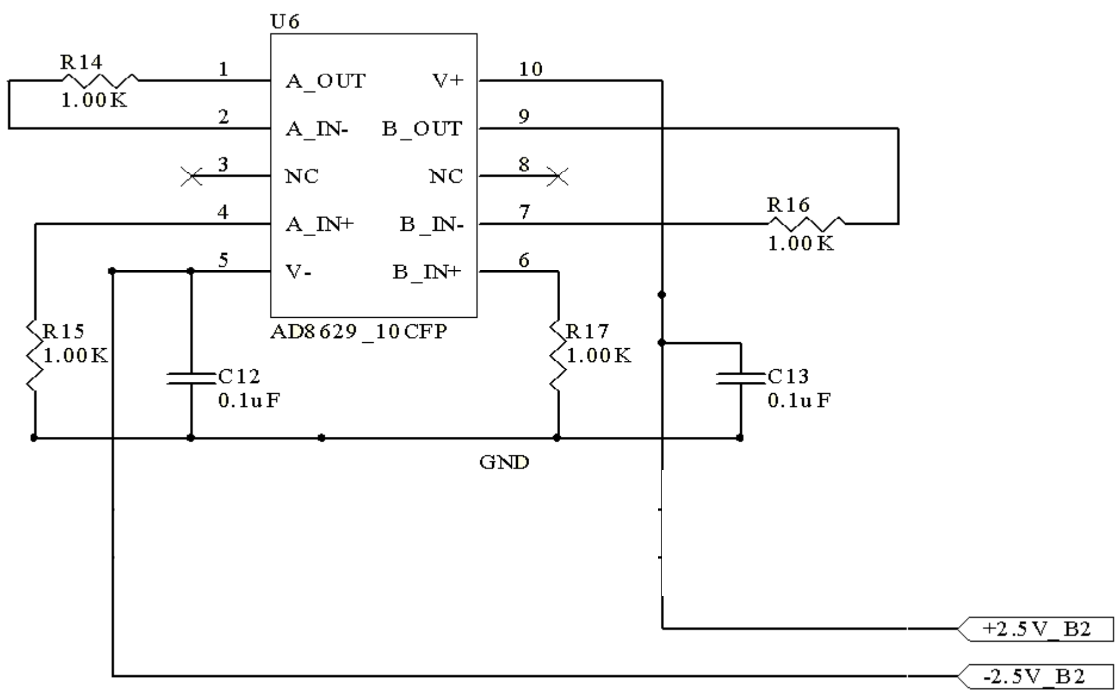


Figure B.1. Schematic drawing of the bias configuration used for the SET test described in this final report.

Aeroflex RAD
5017 N 30th Street
Colorado Springs, CO 80919
(719) 531-0800

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