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SINGLE EVENT LATCH-UP TEST REPORT ADUM3190S

March 2018

Radiation Test Report	
Product:	ADuM3190S
Effective LET:	≤59 MeV-cm^2/mg
Fluence:	1E7 Ions/cm^2
Die Type:	ADUM3190ic/ADUM3190tc
Facilities:	TAMU
Tested:	August 2017

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Test Report for Single Event Effects (SEE) Testing of the ADuM3190 High Stability Isolated Error Amplifier

Customer and PO Number: Analog Devices Inc., 45606934

RTS Job Number: RTS17-J0011

Part Type Tested: ADuM3190 High Stability Isolated Error Amplifier

Lot Number/Date Code: Six (6) devices were supplied by the customer for testing. See photograph of a sample device-under-test in Appendix A.

Quantity of Parts for Testing: Six (6) devices were tested.

Referenced Test Standard(s) and Applicable Documents: ASTM F1192, and EIA/JESD57.

Electrical Test Conditions: Read and record input current. The current and voltage were monitored and recorded in approximately 1 second increments.

Bias Conditions: All devices-under-test (DUT) were biased per customer's bias condition during heavy ion irradiation. See Section 2 for the details of the bias conditions.

Test Software / Hardware: Custom control and monitor software were used to control the test equipment. The test setup is shown in Figure 2-1. The test equipment and calibration dates are shown in Appendix C, Table C-1.

Facility and Radiation Source: Testing took place at the Cyclotron Institute at Texas A&M University on 13 July 2017 and 25 August 2017 using the K500 Cyclotron, the 15 MeV/n beam, in air.

Ion Energy and LET Ranges: Ions from 15 MeV/n beam were used for all testing, specifically the Ta, Pr, Xe, Ag, Kr, Cu, Ar, and Ne ions.

Heavy Ion Flux and Maximum Fluence Levels: Testing was conducted with ion fluxes between 10^2 and 10^5 ions/cm^2. For SEL testing, the beam was shut off when the fluence reached 10^7 ions/cm^2. For SET testing, the beam was shut off when 100 events had been recorded or when the fluence reached 10^6 ions/cm^2. A minimum of 10^7 ions/cm^2 were accumulated where no events are recorded.

Irradiation Temperature: Ambient room temperature for SET testing, 125° C ± 5° C for SEL testing.

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Executive Summary

Six (6) units of the ADuM3190 High Stability Isolated Error Amplifier were tested for Single Event Effects (SEE) with heavy ion irradiation on 13 July 2017 and 24 August 2017 in air and at ambient room temperature at the Cyclotron Institute at Texas A&M University using the K500 Cyclotron and the 15 MeV/n beam.

SEL Summary

The ADuM3190 underwent a destructive event at a LET of 78 MeV-cm^2/mg with no differential voltage across the isolation barrier.

SET Summary

Transients on EA_OUT, EA_OUT2, REF_OUT, and REF_OUT1 with magnitudes up to the rail voltage and durations of a few microseconds to 50 microseconds were observed from LETs of 2.7 to 78 MeV-cm^2/mg.

1.0. Introduction and Test Objectives

This document details the Single Event Effects (SEE) testing report for the ADuM3190 High Stability Isolated Error Amplifier. The test standards used to guide this testing are the ASTM F1192 and the EIA/JESD57. The DUTs was irradiated at the Cyclotron Institute at Texas A&M University (TAMU) using the 15 MeV/n beam, which provided a sufficient range while meeting the LET and energy requirements.

All DUTs were de-processed prior to testing to expose the active areas. The ADuM3190 die is wire bonded; therefore, all exposures took place from the top surface providing a distance to the active layer in the semiconductor material of approximately 5 to 10 µm. See the photograph in Appendix A for a sample of a de-lidded device-under-test.

The objective for SEL testing is to determine the threshold for latch-up in the device under worst case temperature and voltage conditions up to an LET of 78 Mev-cm^2/mg. The SEL testing, the device was irradiated to a maximum fluence of 10^7 ions/cm^2 at a temperature of 125°C.

The objective of the SET test is to provide an expected upset (transient) rate for a given LET and to also provide some statistics regarding the nature (magnitude and duration) of these transients. A preliminary transient cross section of the part with LET's between 2.7 MeV-cm^2/mg and 78 Mev-cm^2/mg was generated. The device was exposed to fluences of 10^6 ions/cm^2 or less if a statistically significant number of single event transients were recorded (i.e., ≥100).

2.0. Test Circuit, Setup, Parameters, Conditions, and Procedures

2.1. Test Circuit and Setup

The ADuM3190 was irradiated using an evaluation board provided by Analog Devices Inc. The SEE test setup for the ADuM3190 is shown in Figure 2-1.

- Four ADuM3190 DUTs were mounted on a DUT board which interfaces with the Memory Test Board.
- A Keithley 2420 Sourcemeter provided the VDD1 voltage and measures the associated current.
- A Keithley 2420 Sourcemeter provided +5 V to the isolated power supply circuitry.
- The housekeeping power supply provided ±5 and +24 volts for the Memory Test Board.
- A Keithley 2410 Sourcemeter provided the ground voltage deferential between the circuitry powered by VDD1 and the circuitry powered by the isolated power supply.
- The Agilent 34970A Data Acquisition Unit and Agilent 34901A Multiplexer Plug-in were used to measure the VDD1 and VDD2 voltages at the DUT board.
- Two PicoScope 6404D Oscilloscopes were used to observed transients occurring on DUT signals.

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- The Shutter Status Monitor is simply a TTL signal used to indicate when the shutter is open and provides a reference signal for the data logging.
- The laptop personal computer (PC) controls the test equipment and records the test data.

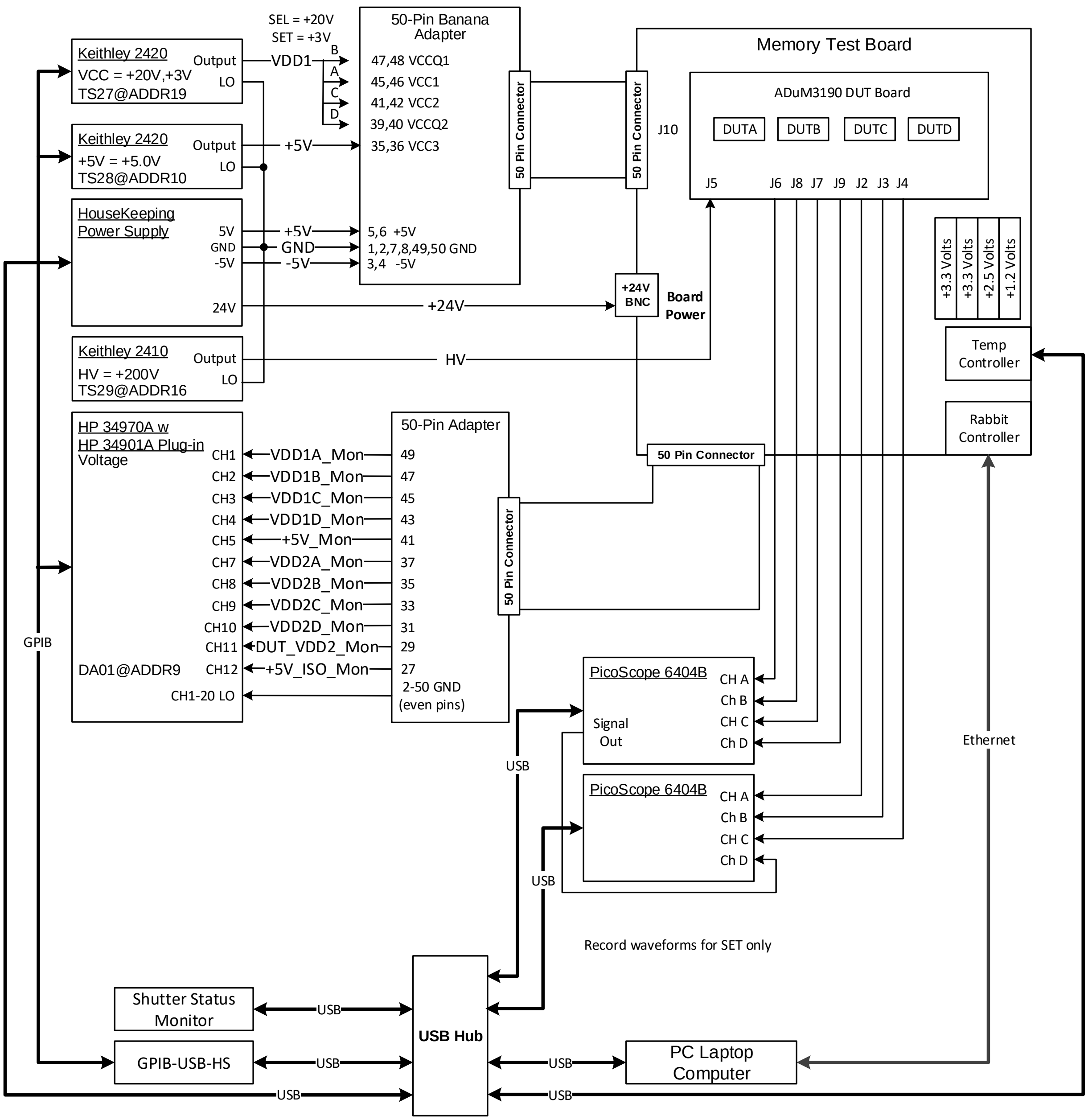

Figure 2-1. ADuM3190 High Stability Isolated Error Amplifier SEE Test Setup.

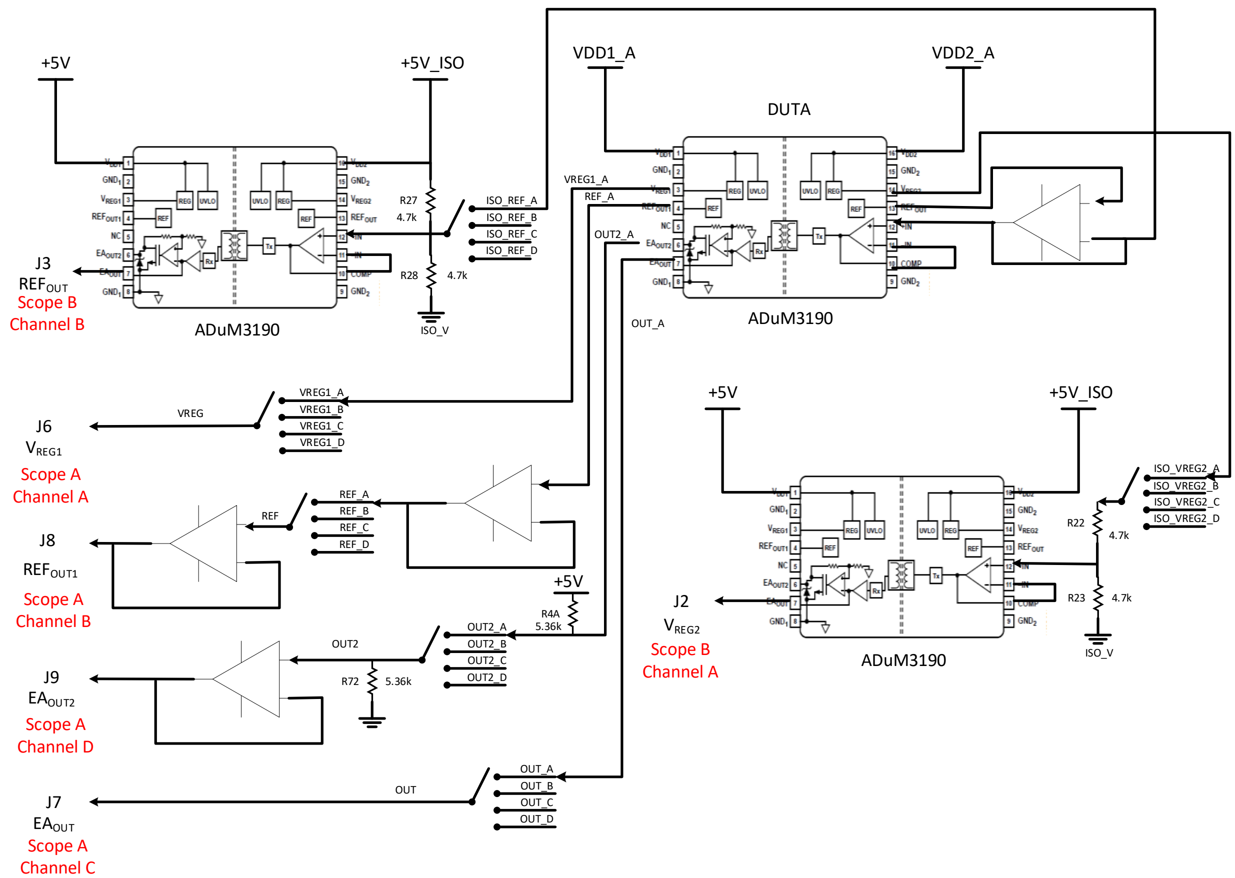

Figure 2-2. ADuM3190 High Stability Isolated Error Amplifier Simplified DUT Board.

Figure 2-2 illustrates the simplified schematic for the ADuM3190 DUT Board. The following signals were observed for transients during SET testing:

- The DUT V_{REG2} signal is routed through the transmit and receive circuits of another ADuM3190 and out the EA_{OUT} signal to connector J2.
- The DUT REF_{OUT} signal is routed through an op amp and then through the transmit and receive circuits of another ADuM3190 and out the EA_{OUT} signal to connector J3.
- The DUT V_{REG1} signal is output directly to connector J6.
- The DUT REF_{OUT1} signal is routed through two op amps to connector J8.
- The DUT REF_{OUT} signal is routed through an op amp and to the DUT +IN signal through the DUT's transmit and receive circuits and out DUT EA_{OUT} and DUT EA_{OUT2} signals. The DUT EA_{OUT} signal is connected to J7.
- The DUT EA_{OUT2} signal is routed through an op amp and to connector J9.

The DUT board also has the capability of providing either +5 V or +20 V to VDD2.

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2.2. Test Parameters

Parameters measured at approximately one second increments during both the SEL and SET tests were:

- The DUT temperature (from our temperature controller)
- The VDD1 and VDD2 voltage at the DUT
- The VDD1 input current
- The +5 V input current
- The ground voltage differential power supply input current
- The +5V voltage and the +5/+20 V voltage
- Beam shutter status

Additional parameters measured during SET testing were:

- The V_{REG1}, V_{REG2}, REF_{OUT}, REF_{OUT1}, EA_{OUT}, and EA_{OUT2} transient waveforms.

2.3. Test Conditions

The supply voltages and ion fluence for the SEE testing were as follows:

Table 2-1. ADuM3190 Test Conditions.

	SEL	SET
DUT Temperature	125° C	Ambient
VDD1	+20V	+3V
VDD2	+20V (Above isolated ground)	+5V (Above isolated ground)
Max. fluence	10^7 ions/cm^2	10^6 ions/cm^2 or 100 events
Trigger Level		±200 mV centered around the nominal output voltage of the signal

The signals monitored and recorded during the test were routed approximately twenty feet via coaxial cable to the control room.

2.4. SET Test Procedure

The current limit on the VDD1 and +5V power supplies was set to 100 mA.

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The following general SET test procedure was used:

1. Power up the DUT.
2. Select the desired ion and angle of incidence.
3. Turn on the ion beam while observing, monitoring and logging the power supply currents and recording the transients through the FPGA on the memory test motherboard.
4. Turn off the beam when either the specified number of transients is recorded or the fluence reaches 10^6 ions/cm^2.
5. Repeat the procedure beginning at step 2 until the DUT has been irradiated across the desired range of LETs.

During heavy ion exposure, two PicoScope 6404D Oscilloscopes were used to record the transient waveforms. For each test, the oscilloscope was set to trigger at ±200 mV because of the amplitude of the transients. The trigger on the oscilloscope connected to V_{REG1}, REF_{OUT}, EA_{OUT}, and EA_{OUT2} were OR'd. The arbitrary signal generator of this oscilloscope was configured to provide an input to the other oscilloscope, pulsing when the trigger occurred. The trigger on the oscilloscope connected to V_{REG2}, REF_{OUT} , and the signal from the other oscilloscope were initially OR'd and then only V_{REG2} and REF_{OUT} were OR'd.

2.5. SEL Test Procedure

The current limit on the power supplies was set to 300 mA initially and then to 500 mA. The following general SEL test procedure was used:

1. Power up the DUT and wait for it to attain the desired test temperature.
2. Select the desired ion and angle of incidence.
3. Turn on the ion beam, observe/monitor/log device current.
4. If no latch up occurs or the fluence reaches 10^7 ions/cm^2, select the next ion and desired angle of incidence and repeat the procedure beginning at step 3.
5. If the device latches up, shut off the beam and power down the device.
6. Reapply power to the device and check currents for a destructive latch up.
7. Test the remaining DUTs at the highest effective LET in which no latch up is observed beginning at step 1.

3. Test Results and Discussion

3.1. SEL Test Results

Table 3-1 summarizes the test runs and test conditions for the SEL test runs. All runs were performed with an angle of incidence of 0°.

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Table 3-1. ADuM3190 SEL Test Run Log.

Run	DUT	Ion	Effective LET (MeV·cm^2/mg)	Effective fluence (ions/cm^2)	Ground Differential Voltage (V)	Comment
74	2A	Ta	78	1.00E+07	0	Part functioning after run
75	1A	Ta	78	9.98E+06	0	See Run 75 Description
76	1A	Ta	78	1.01E+07	0	See Run 76 Description
77	1D	Ta	78	1.00E+07	0	Part functioning after run
78	2D	Ta	78	9.98E+06	0	EA_{OUT} and EA_{OUT2} failed, see Run 78 Description
79	2A	Pr	59	1.00E+07	0	Part functioning after run
80	1A	Pr	59	1.00E+07	0	Part functioning after run
81	1D	Pr	59	1.00E+07	0	Part functioning after run
83	1A	Ag	43	1.00E+07	0	Part functioning after run
87	2A	Ag	43	9.98E+06	0	Part functioning after run

The current plots for each of the SEL and SET runs are presented in Appendix E. In each plot the approximate time of when the ion beam were turned on and off are marked in red.

DUT 2A was irradiated at a LET of 78 MeV-cm^2/mg in Run 74 and a LET of 59 MeV-cm^2/mg in Run 79. However, the +5 V current indirectly providing current to the DUT VDD2 increased during both runs. Figure 3-1 illustrates the +5 V current plots for Runs 74 and 79. During Run 74, the current increased from 220 mA to 260 mA. At the start of Run 79, the current started at 260 mA and increased to 280 mA. During Run 87, this DUT was used again, but this time the current began at 280 mA and remained for the entire run. The VDD1 current remained the same during Runs 74 and 79, as shown in Figure 3-2. ADuM3190 DUT 2A was functioning properly after Runs 74 and 79.

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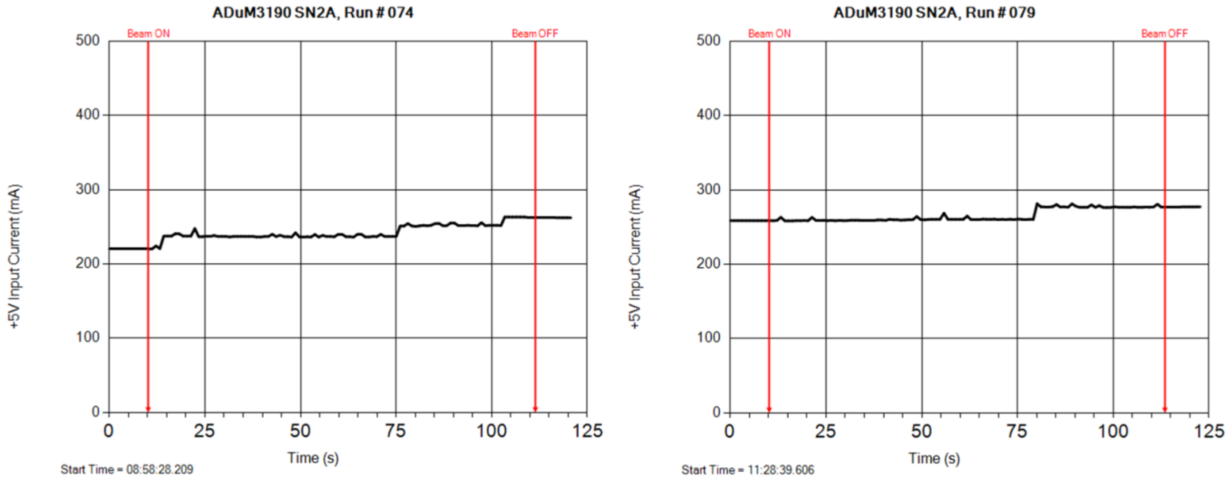

Figure 3-1. +5Volt Current for Runs 74 and 79.

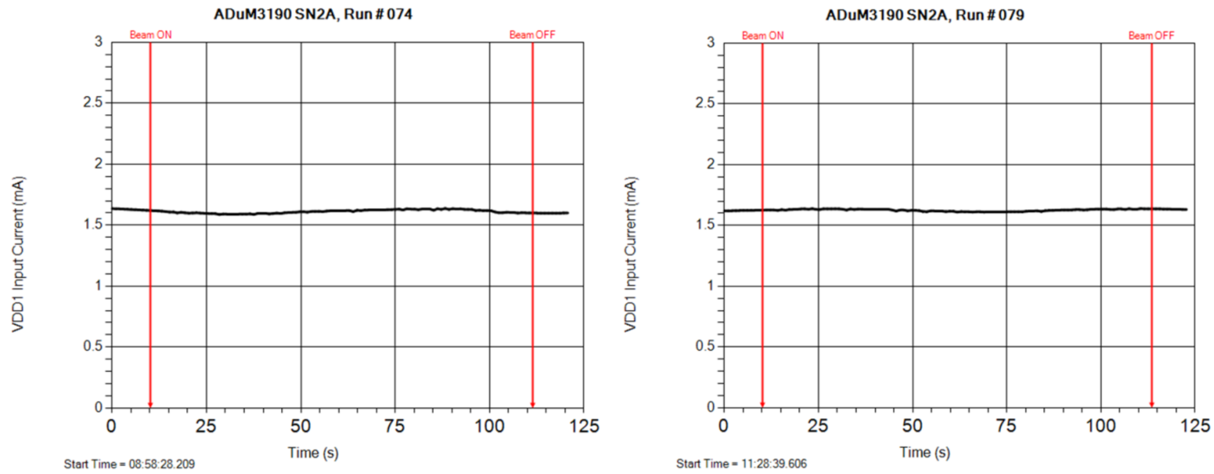

Figure 3-2. VDD1 Current for Runs 74 and 79.

In Run 75 using DUT 1A, the VDD1 current dropped from 1.6 mA to 1.25 mA in the middle of the run. At the same time, the +5 V current jumped 220 mA to the current limit on the sourcemeter of 300 mA. Figure 3-3 illustrates the VDD1 current and +5 V current during Run 75.

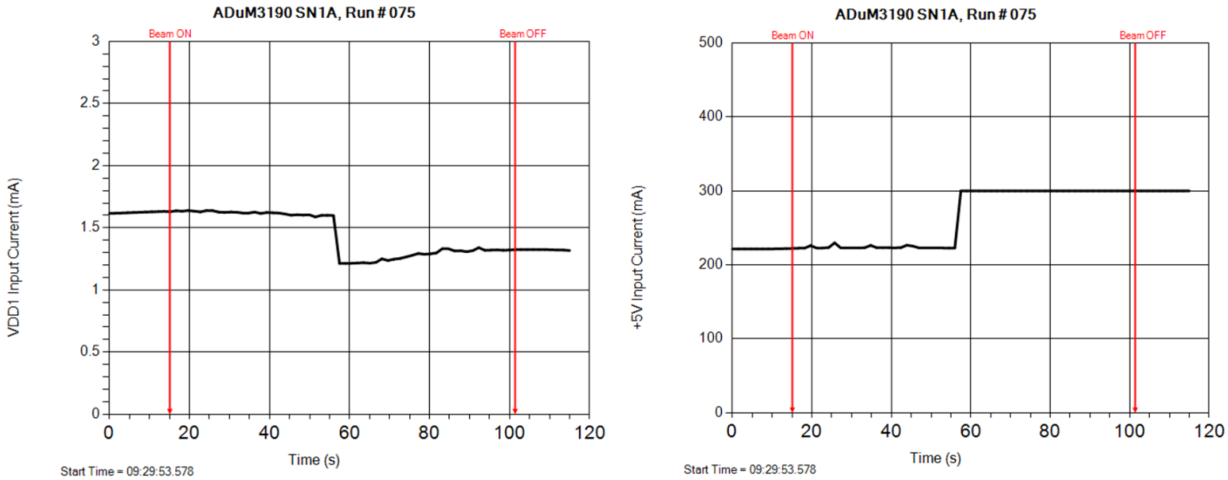

Figure 3-3. VDD1 Current and +5 V Current for Run 75.

In Run 76 using DUT 1A, the current limit on the +5 V sourcemeter was increased to 500 mA. Figure 3-4 illustrates the VDD1 current and +5 V current. The nominal current on the +5 V sourcemeter is 400 mA, where it started at 220 mA at the beginning of Run 75. In the remaining runs using DUT 1A (Runs 80 and 83), the nominal current is approximately 400 mA. During Run 76, the VDD1 current spiked to 19.5 mA but returned to nominal of 1.6 mA 2 seconds later. Even with the increased current on the +5 V, the DUT 1A is still functioning properly.

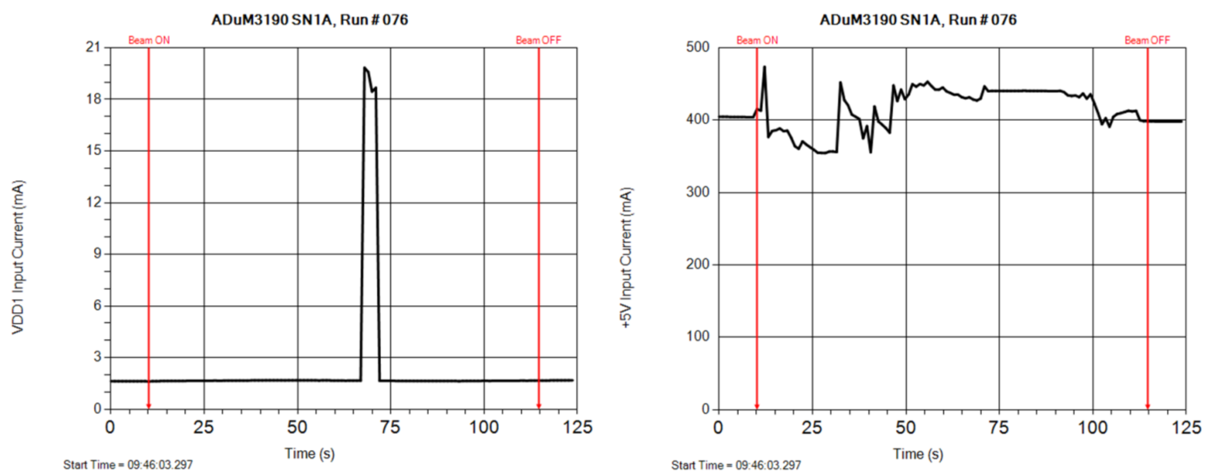

Figure 3-4. VDD1 Current and +5 V Current for Run 76.

DUT 1D was irradiated at a LET of 78 MeV-cm^2/mg in Run 77 and a LET of 59 MeV-cm^2/mg in Run 81. However, the +5 V current indirectly providing current to the DUT VDD2 increased during both runs. Figure 3-5 illustrates the +5 V current plots for Runs 77 and 81. During Run 77, the current increased from 220 mA to 260 mA. At the start of Run 77, the current started at 260 mA and increased to 280 mA.

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The VDD1 current remained the same during Runs 77 and 81, as shown in Figure 3-6. ADuM3190 DUT 1D was functioning properly after Runs 77 and 81.

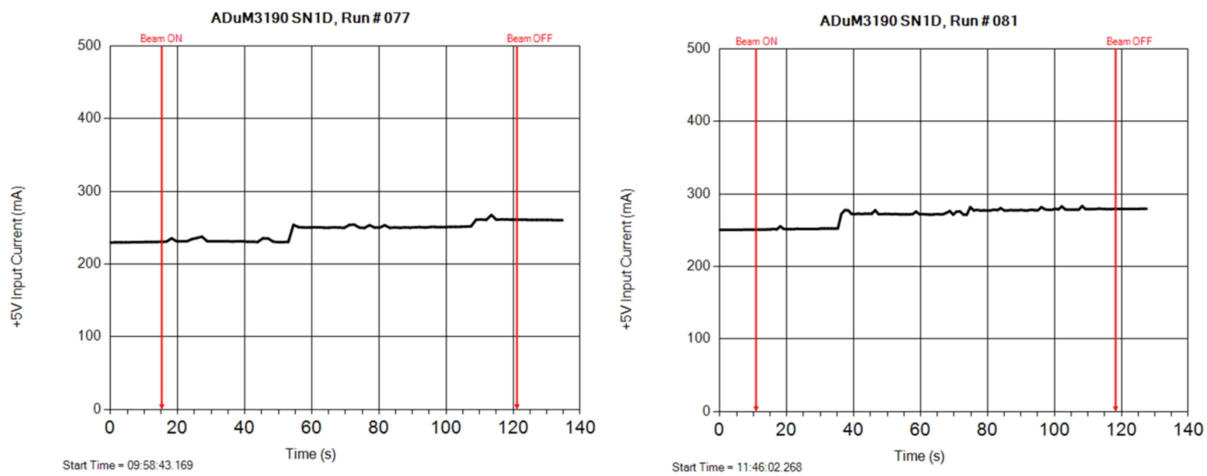

Figure 3-5. +5Volt Current for Runs 77 and 81.

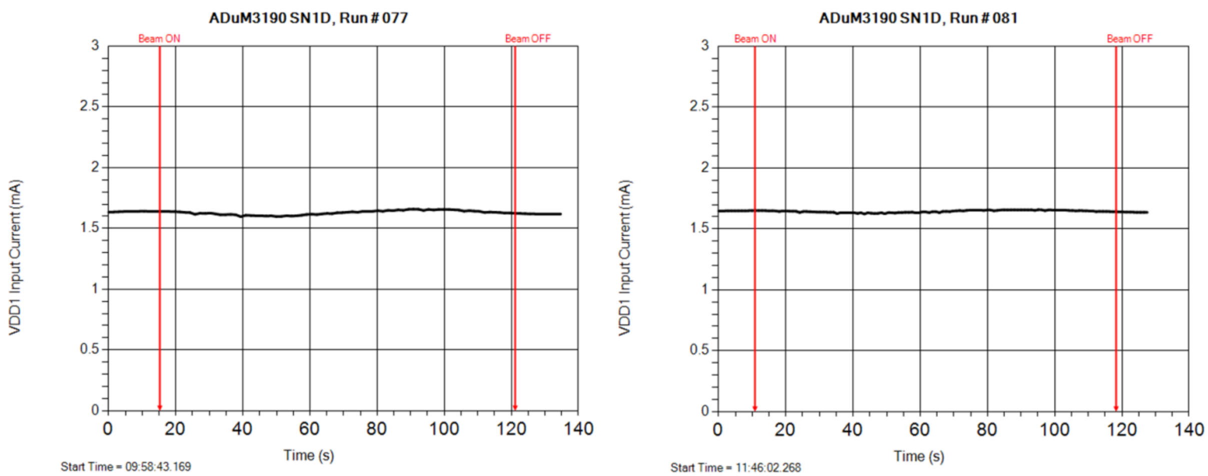

Figure 3-6. VDD1 Current for Runs 77 and 81.

DUT 2D was irradiated at an LET of 78 MeV-cm^2/mg in Run 78. Figure 3-7 illustrates the VDD1 current and +5 V current during Run 78. During the run, the VDD1 current dropped at the same time as the EA_{OUT} and EA_{OUT2} signals stopped functioning. ADuM3190 DUT 2D fail during Run 78.

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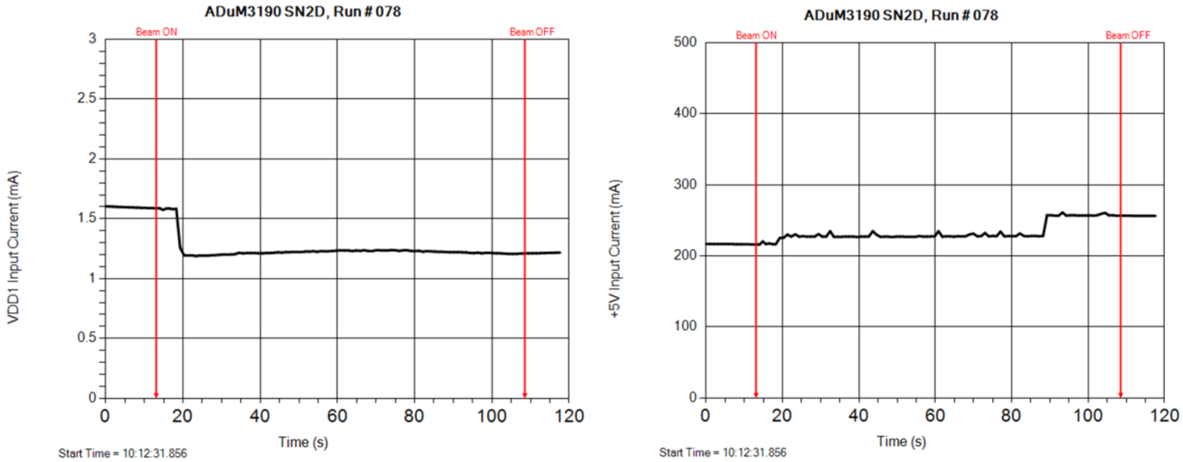

Figure 3-7. VDD1 Current and +5 V Current for Run 78.

DUT 1A was irradiated at a LET of 59 MeV-cm^2/mg in Run 80. The +5 V current was still elevated to 400 mA during this run, however, DUT 1A was function during the entire run.

DUT 1A was irradiated at a LET of 43 in run 83. After run 83, ADuM3190 DUT 1A was still functioning. However, the +5 V nominal current, which was already elevated during Run 75, changed during Run 83 and remained at an even higher level of 450 mA in subsequent runs. Note that ADuM3190 DUT 1A was still functioning properly after Run 83.

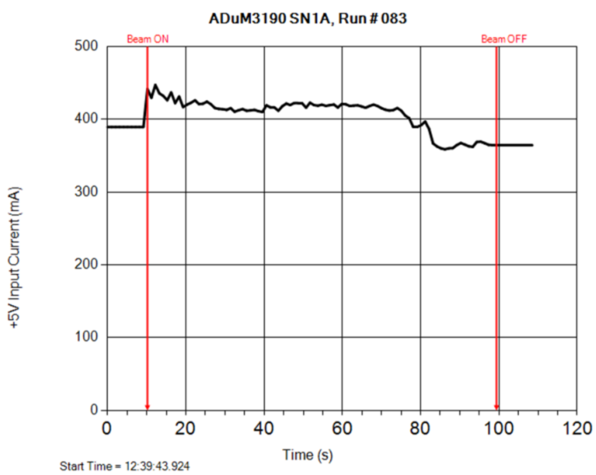

Figure 3-8. +5 V Current for Run 83.

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DUT 2A was irradiated at a LET of 43 MeV-cm^2/mg in Run 87. DUT 2A was functioning properly after the run. Figure 3-9 illustrates the VDD1 current and the +5 V current during Run 87.

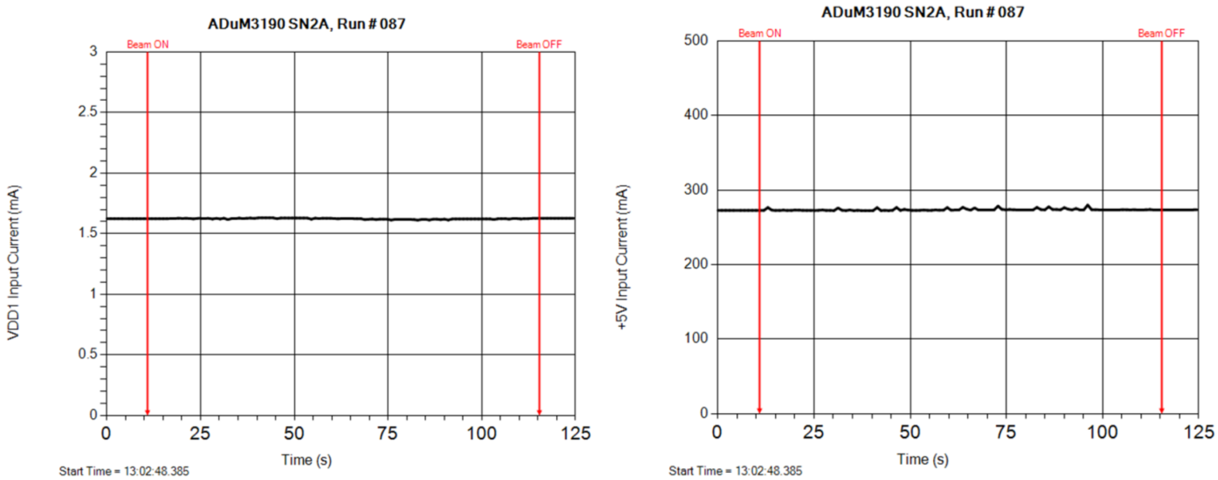

Figure 3-9. VDD1 Current and +5 V Current for Run 87.

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3.2. SET Test Results

The SET results for the ADuM3190 were evaluated with the tantalum, xenon, copper, argon, and neon ions. The components were tested at ambient temperature during the SET runs with the exception of Run 183, which was tested at a temperature of 125° C.

A chronological listing of each SET run, including test conditions and results, is shown in Table 3-2. Note that SN 2 was reused in SEL testing and is labeled SN 1D in the above SEL discussion. All transient waveforms have been plotted and are available upon request.

Table 3-2. ADuM3190 SET Test Run Log.

Run	DUT	Ion	Effective LET (MeV·cm^2/mg)	Effective range (µm)	Scope A Effective Fluence (ions/cm^2)	Scope B Effective Fluence (ions/cm^2)
169	1	Xe	52	113.7	1.89E+05	1.89E+05
171	2	Xe	52	113.7	4.39E+04	4.39E+04
172	2	Xe	52	113.7	8.84E+04	4.54E+05
173	1	Xe	52	113.7	7.61E+04	2.98E+05
174	3	Xe	52	113.7	1.16E+05	1.08E+05
175	3	Cu	20	129.5	2.77E+05	4.44E+05
176	2	Cu	20	129.5	4.59E+05	5.72E+05
177	1	Cu	20	129.5	4.41E+06	1.20E+06
179	1	Ar	8.4	186.1	2.00E+06	1.05E+06
180	2	Ar	8.4	186.1	7.61E+05	5.10E+05
181	2	Ne	2.7	273.5	9.90E+05	9.90E+05
182	1	Ne	2.7	273.5	1.75E+06	1.75E+06
183	1	Ta	78	112.6	2.34E+05	2.13E+05
186	2	Ta	78	112.6	2.49E+05	1.61E+05
187	3	Ta	78	112.6	2.23E+05	1.69E+05

The SET analysis starts with finding the cross section of the output signals individually. There was a relationship that occurred between the REF_{OUT} signal and EA_{OUT} and EA_{OUT2}, since REF_{OUT} was routed back through the DUT and output on EA_{OUT} and EA_{OUT2}. Therefore, a transient on REF_{OUT} would cause a transient to appear on EA_{OUT} and EA_{OUT2}, so the REF_{OUT} transient total was subtracted from the EA_{OUT} and EA_{OUT2} transient count in Table 3-3.

The V_{REG1} and V_{REG2} signal are not included in Table 3-3 because there were no transients observed on those signals.

Table 3-3. ADuM3190 Individual Signal Transient Count

Run	DUT	LET (MeV-cm2/mg)	REF_{OUT1} Transients	REF_{OUT1} Transeint Cross Section	EA_{OUT} Transients	EA_{OUT} Transient Cross Section	EA_{OUT2} Transients	EAOUT2 Transient Cross Section	REF_{OUT} Transients	REF_{OUT} Transient Cross Section
169	1	52	90	4.76E-04	97.0	6.88E-04	56	2.96E-04	71	3.76E-04
171	2	52	19	4.33E-04	20.1	7.29E-04	10	2.28E-04	26	5.92E-04
172	2	52	37	4.19E-04	206.5	7.35E-04	18	2.04E-04	51	4.41E-04
173	1	52	52	6.83E-04	152.1	9.20E-04	24	3.15E-04	23	3.36E-04
174	3	52	91	7.84E-04	60.2	1.13E-03	39	3.36E-04	100	9.26E-04
175	3	20	73	2.64E-04	231.4	5.02E-04	19	6.86E-05	65	2.25E-04
176	2	20	58	1.26E-04	91.8	2.70E-04	17	3.70E-05	81	1.75E-04
177	1	20	110	2.49E-05	246.2	4.24E-05	49	1.11E-05	25	5.08E-05
179	1	8.4	69	3.45E-05	194.3	5.00E-05	14	7.00E-06	0	0.00E+00
180	2	8.4	0	0.00E+00	70.9	6.44E-05	10	1.31E-05	17	5.49E-05
181	2	2.7	0	0.00E+00	32.6	2.12E-05	2	2.02E-06	11	1.11E-05
182	1	2.7	27	1.54E-05	61.6	1.54E-05	0	0.00E+00	0	0.00E+00
183	1	78	211	9.02E-04	95.7	1.23E-03	114	4.86E-04	100	4.69E-04
186	2	78	157	6.31E-04	49.1	9.36E-04	53	2.13E-04	100	6.21E-04
187	3	78	149	6.68E-04	37.8	1.16E-03	88	3.93E-04	100	5.92E-04

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Figure 3-10 shows the plot of cross-sections from Table 3-3 along with a bounding Weibull curve. The parameters for the Weibull are: Shape=1.5, Width=30, Saturation=1e-3, and Onset = 0.1.

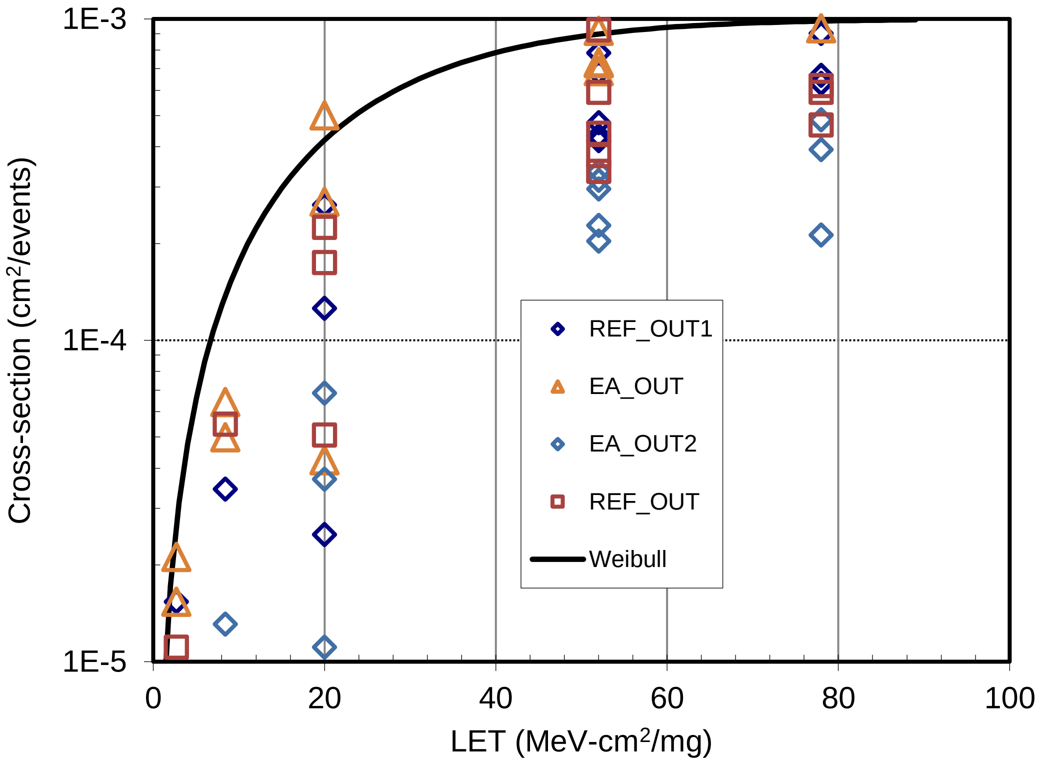

Figure 3-10. Cross-section of single transients with bounding Weibull curve.

While Table 3-3 lists the number of transients on each signal and its transient cross section, it does not give a full characterization of the transients. The transients appeared on a combination of signals most of the time. Table 3-4 lists number of transients and transient cross section for the following combination of signals with transients:

- REF_{OUT1} and EA_{OUT}
- EA_{OUT} and EA_{OUT2}
- REF_{OUT1}, EA_{OUT}, and EA_{OUT2}
- EA_{OUT} Alone (No transients on other signals)
- EA_{OUT2} Alone (No transients on other signals)

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Table 3-4. ADuM3190 Combination and Alone Transient Count

Run	DUT	Ion	REF$_{OUT1}$ and EA$_{OUT}$ Transients	REF$_{OUT1}$ and EA$_{OUT}$ Transeint Cross Section	EA$_{OUT}$ and EA$_{OUT2}$ Transients	REF$_{OUT1}$, EA$_{OUT}$ and, EA$_{OUT2}$ Transient Cross Section	REF$_{OUT1}$, EA$_{OUT}$, and EA$_{OUT2}$ Transients	REF$_{OUT1}$, EA$_{OUT}$, and EA$_{OUT2}$ Transient Cross Section	EA$_{OUT}$ Alone Transients	EA$_{OUT}$ Alone Transient Cross Section	EA$_{OUT2}$ Alone Transients	EA$_{OUT2}$ Alone Transient Cross Section
169	1	Xe	47	2.5E-04	13	6.9E-05	43	2.3E-04	27	1.4E-04	0	0
171	2	Xe	16	3.6E-04	7	1.6E-04	3	6.8E-05	6	1.4E-04	0	0
172	2	Xe	27	3.1E-04	8	9.0E-05	10	1.1E-04	20	2.3E-04	0	0
173	1	Xe	34	4.5E-04	6	7.9E-05	18	2.4E-04	12	1.6E-04	0	0
174	3	Xe	59	5.1E-04	5	4.3E-05	32	2.8E-04	35	3.0E-04	2	1.7E-05
175	3	Cu	54	1.9E-04	0	0.0E+00	19	6.9E-05	66	2.4E-04	0	0
176	2	Cu	51	1.1E-04	10	2.2E-05	7	1.5E-05	56	1.2E-04	0	0
177	1	Cu	93	2.1E-05	32	7.3E-06	17	3.9E-06	45	1.0E-05	0	0
179	1	Ar	57	2.9E-05	1	5.0E-07	12	6.0E-06	30	1.5E-05	1	5.0E-07
180	2	Ar	0	0	0	0	0	0	49	6.4E-05	10	1.3E-05
181	2	Ne	0	0	0	0	0	0	21	2.1E-05	2	2.0E-06
182	1	Ne	27	1.5E-05	0	0	0	0	0	0	0	0
183	1	Ta	143	6.1E-04	40	1.7E-04	68	2.9E-04	36	1.5E-04	6	2.6E-05
186	2	Ta	125	5.0E-04	16	6.5E-05	32	1.3E-04	60	2.4E-04	5	2.0E-05
187	3	Ta	81	3.6E-04	20	8.9E-05	68	3.0E-04	90	4.0E-04	0	0

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Figure 3-11 shows a plot of the combination and along cross-sections from table 3-4 along with a bounding Weibull curve. The Weibull curve parameters are: Shape=1.5, Width=40, Saturation=8e-4, and Onset=0.01.

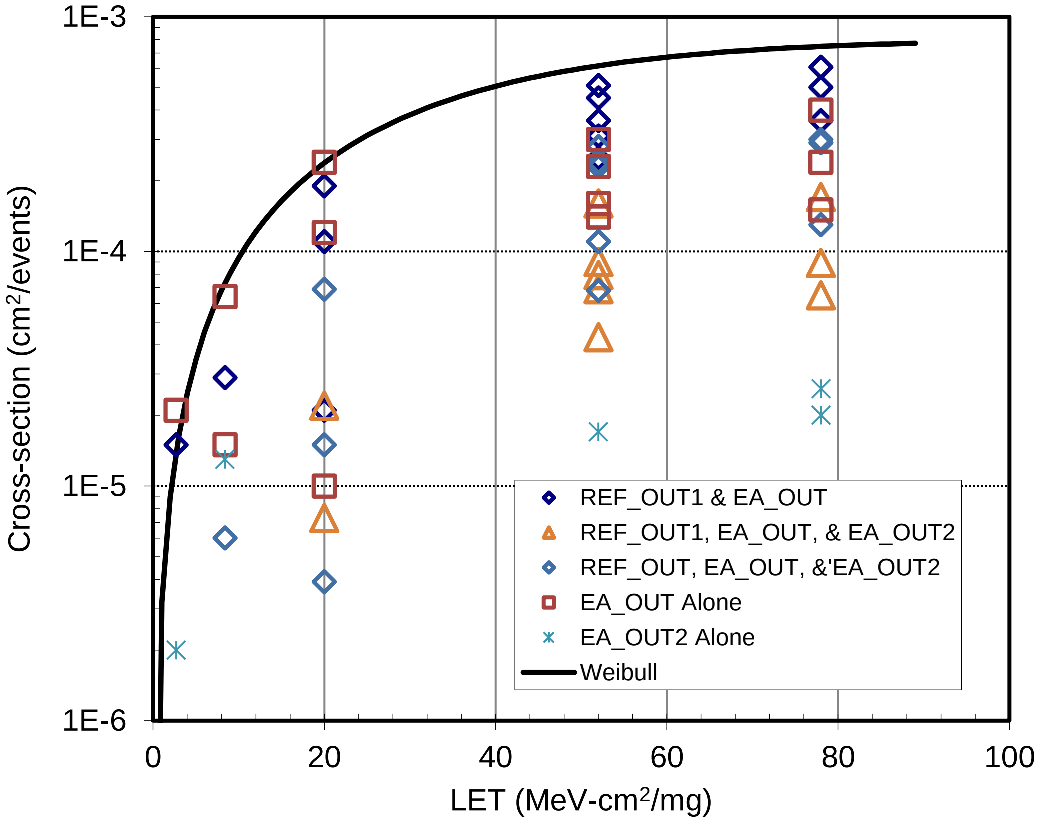

Figure 3-11. Cross-section of combo and alone transients with bounding Weibull curve.

There were many oscilloscope plots. The following figures show a representative sample of the transients. The complete set of waveforms are available on request. As mentioned above, most of the transients appeared on a combination of signals. On the oscilloscope plots REF_{OUT1} is titled REF1, EA_{OUT} is titled EA_OUT, EA_{OUT2} is titled EA_OUT2, and REF_{OUT} is titled REF2.

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Figures 3-12 through 3-14 show transient combinations on REF_{OUT1} and EA_{OUT}.

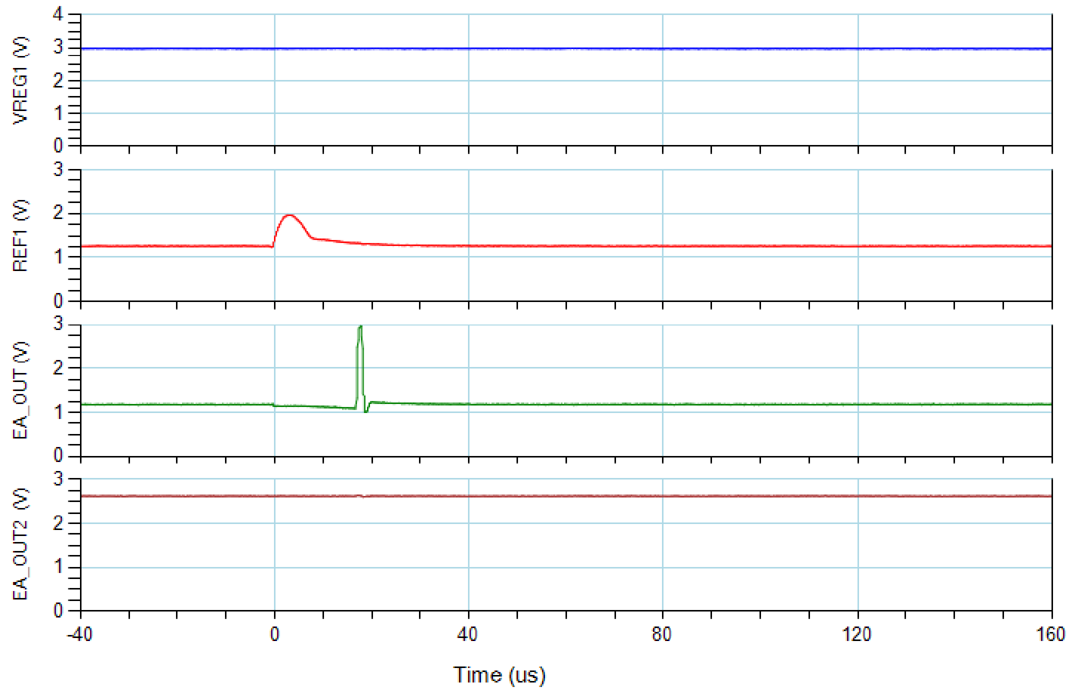

Figure 3-12. ADuM3190 SN1 Scope A, Run # 169, Frame # 093

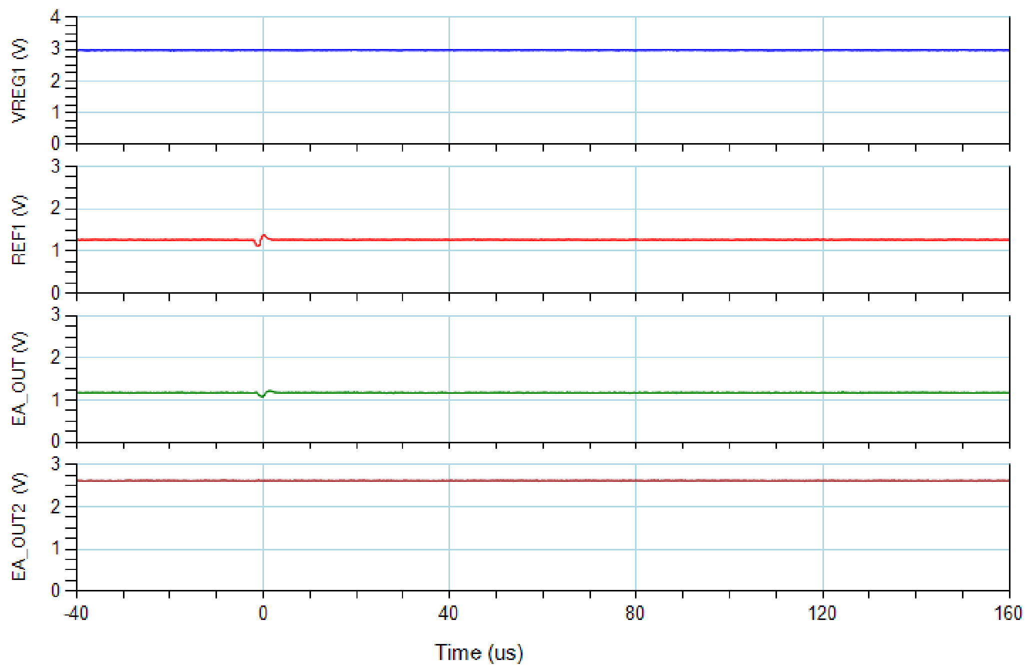

Figure 3-13. ADuM3190 SN1 Scope A, Run # 169, Frame # 003

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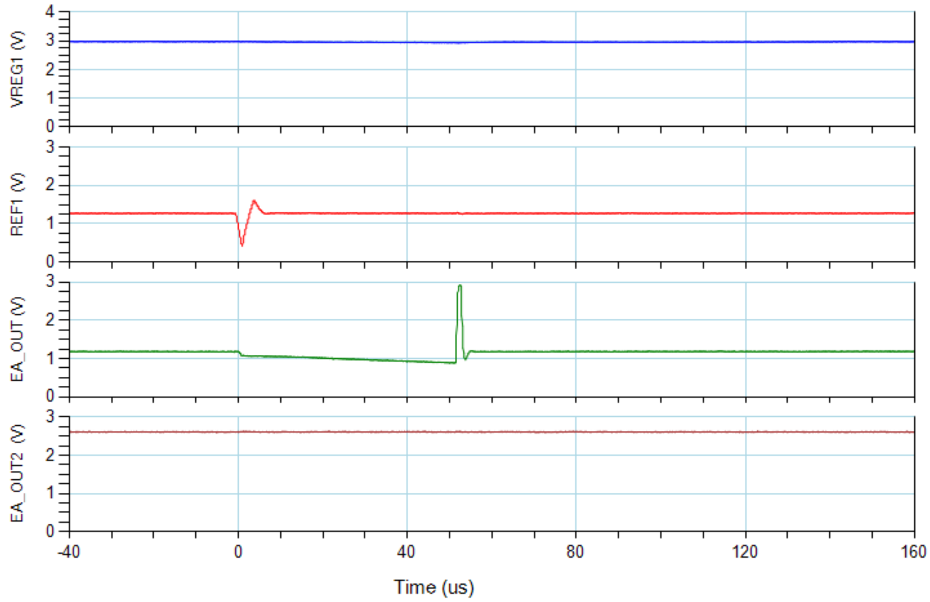

Figure 3-14. ADuM3190 SN2 Scope A, Run # 186, Frame # 034

Figures 3-15 through 3-19 show transient combinations on EA_{OUT} and EA_{OUT2}.

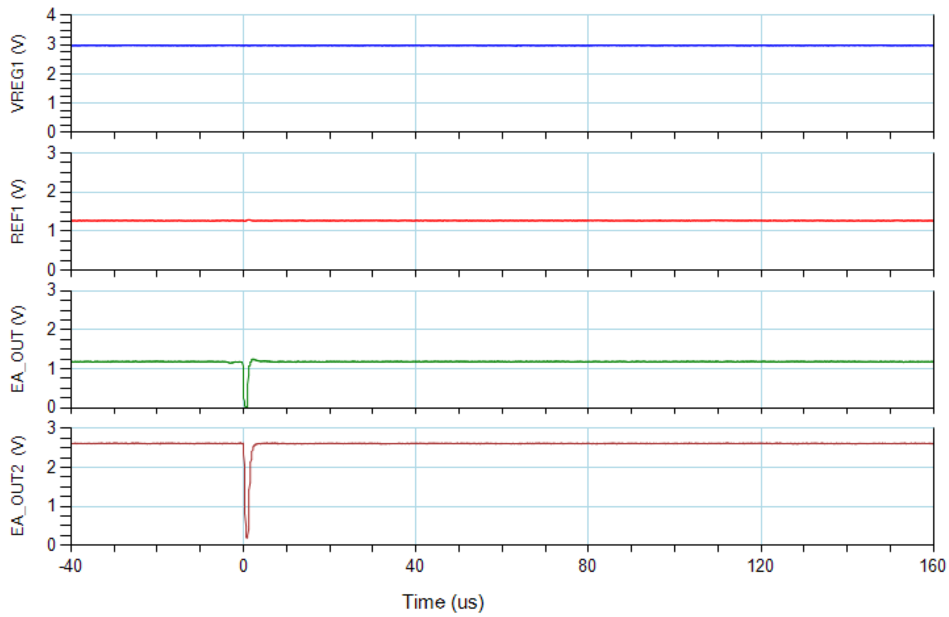

Figure 3-15. ADuM3190 SN2 Scope A, Run # 186, Frame # 035

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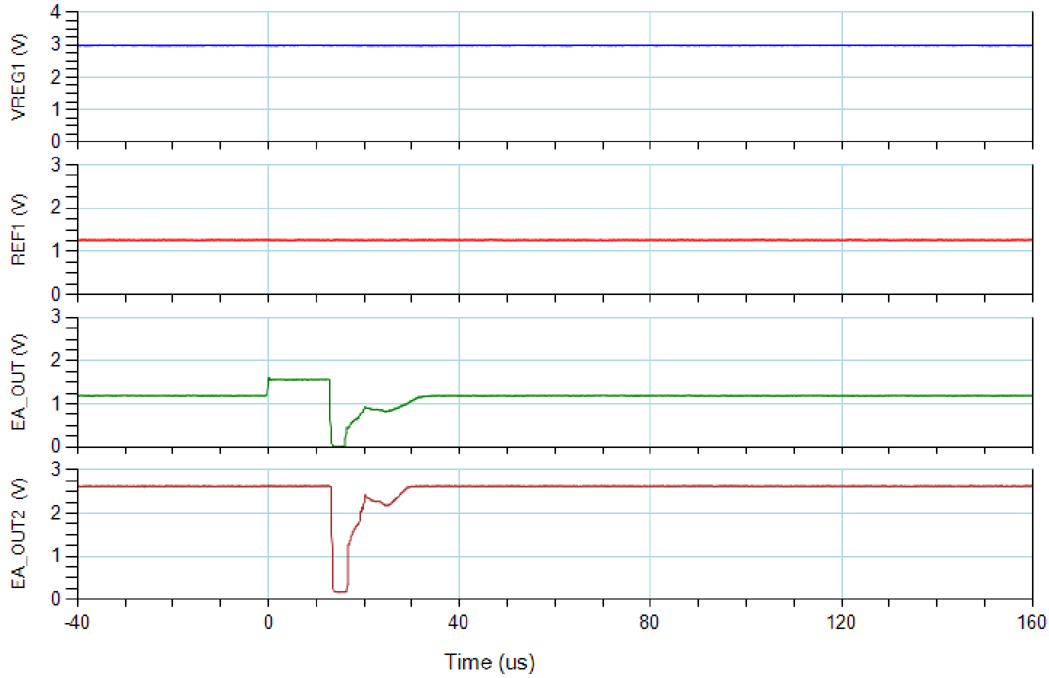

Figure 3-16. ADuM3190 SN3 Scope A, Run # 174, Frame # 075

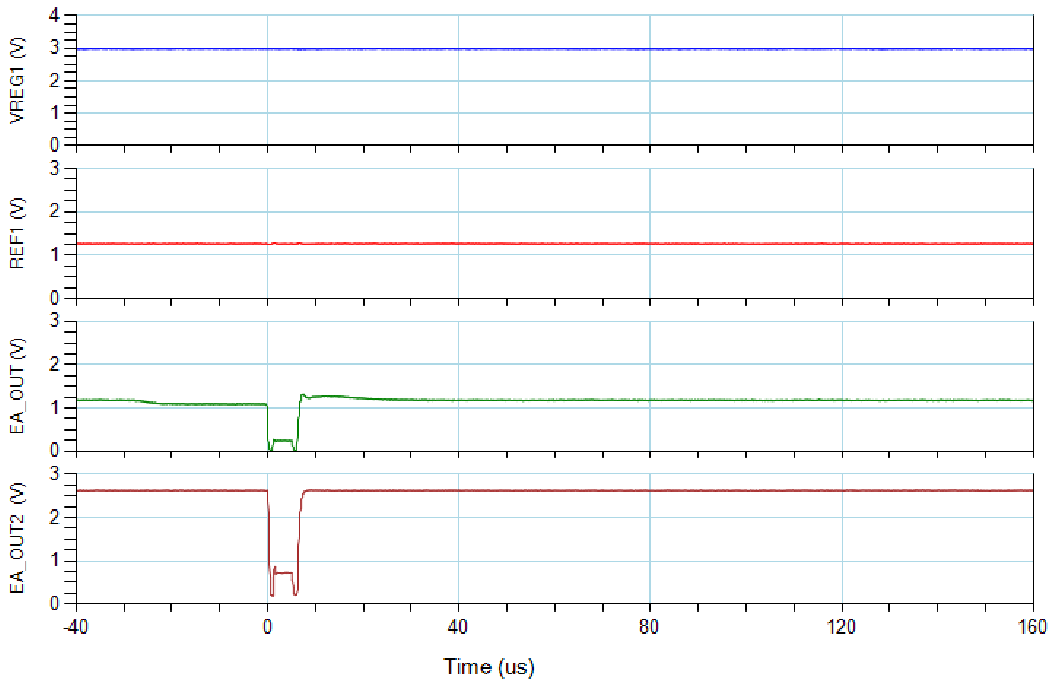

Figure 3-17. ADuM3190 SN1 Scope A, Run # 169, Frame # 033

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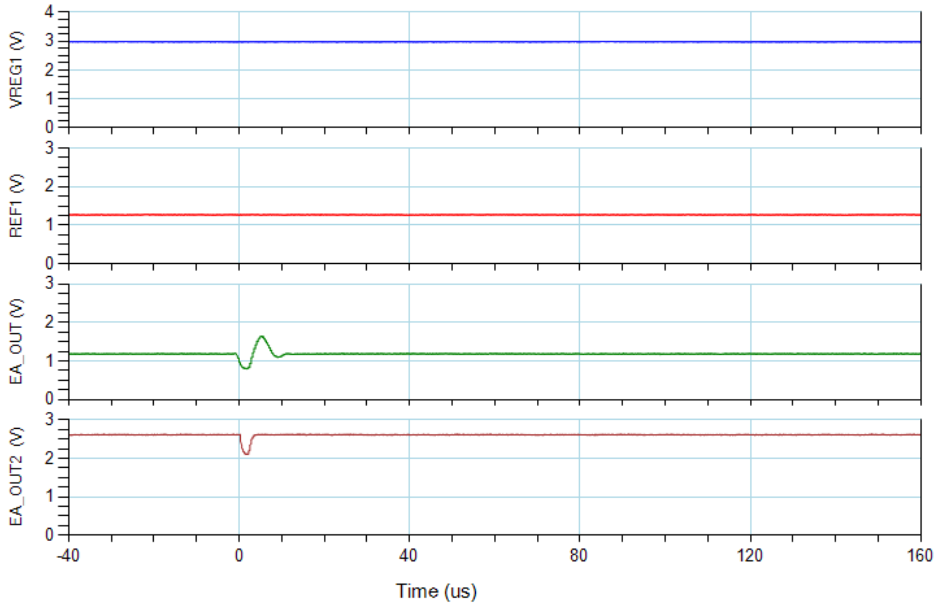

Figure 3-18. ADuM3190 SN2 Scope A, Run # 186, Frame # 172

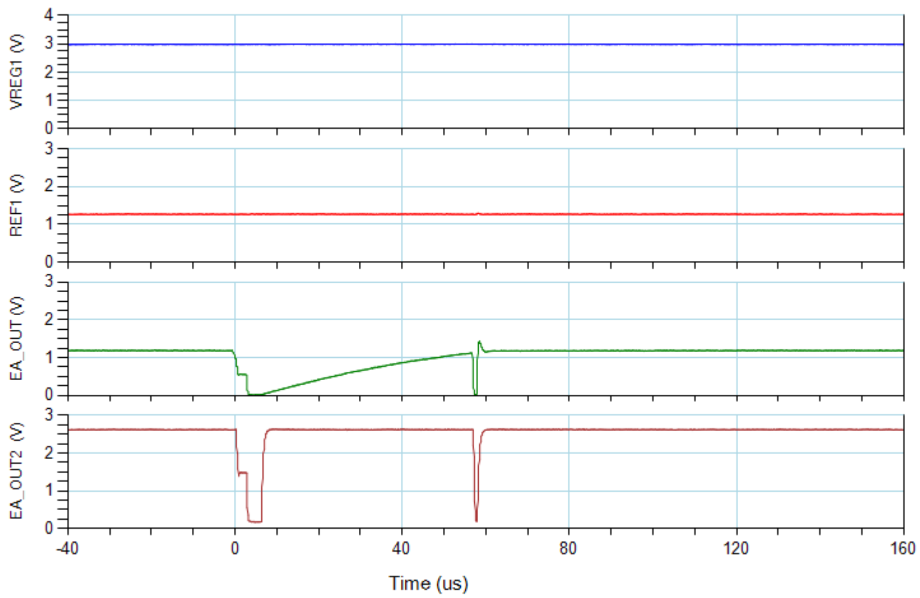

Figure 3-19. ADuM3190 SN3 Scope A, Run # 174, Frame # 147

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Figures 3-20 through 3-22 show transient combinations on REF_{OUT1}, EA_{OUT} and EA_{OUT2}.

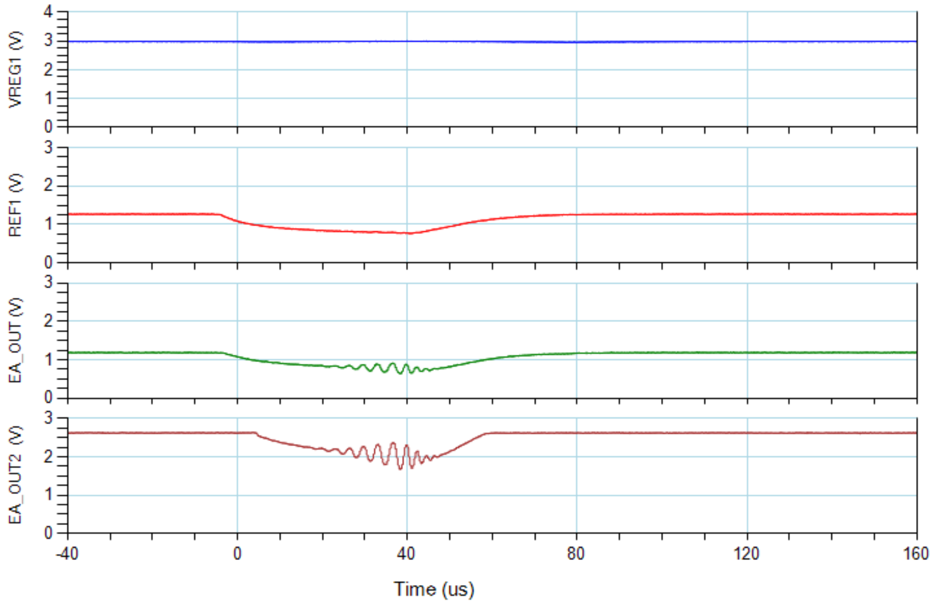

Figure 3-20. ADuM3190 SN3 Scope A, Run # 174, Frame # 109

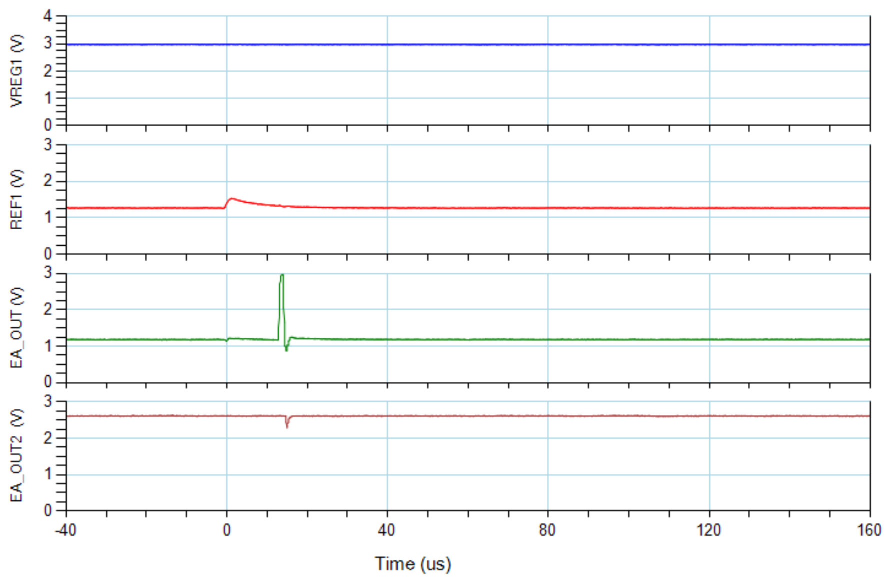

Figure 3-21. ADuM3190 SN2 Scope A, Run # 186, Frame # 215

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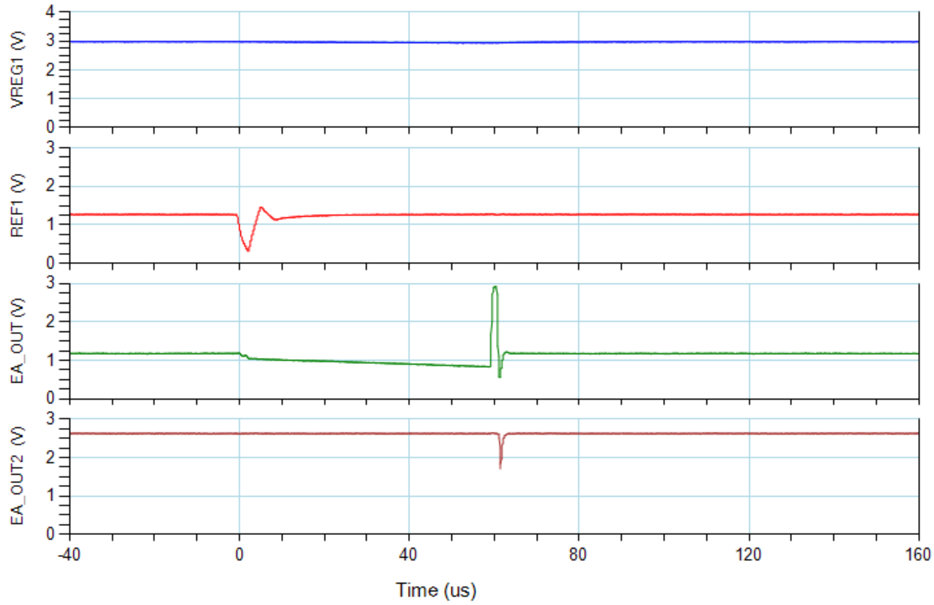

Figure 3-22. ADuM3190 SN1 Scope A, Run # 177, Frame # 043

Figures 3-23 through 3-25 show transients on EA_{OUT}.

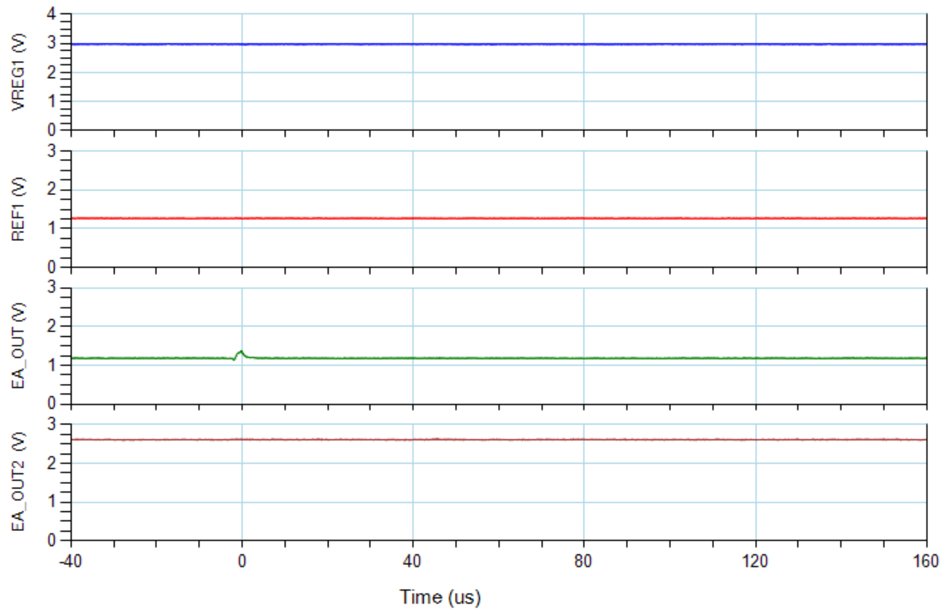

Figure 3-23. ADuM3190 SN2 Scope A, Run # 186, Frame # 231

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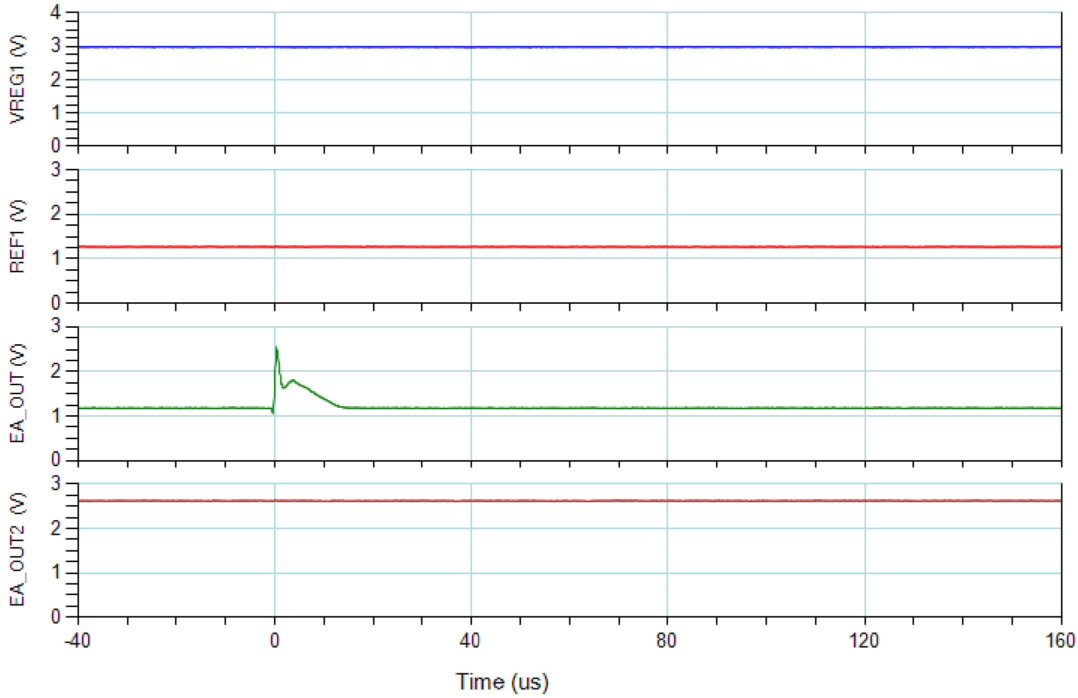

Figure 3-24. ADuM3190 SN1 Scope A, Run # 169, Frame # 062

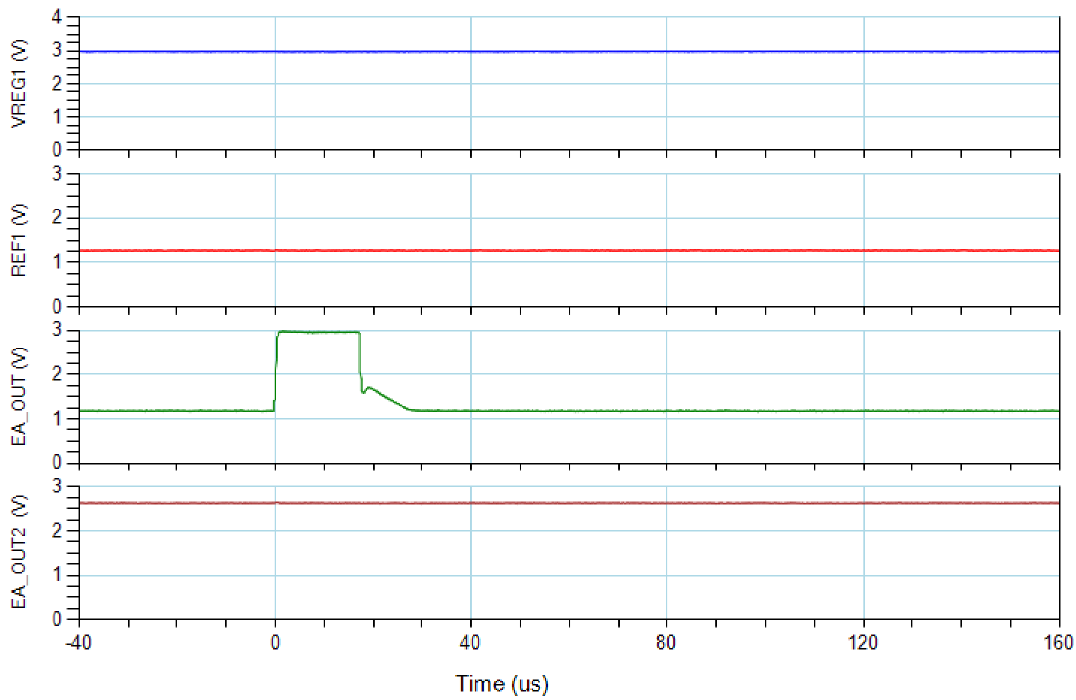

Figure 3-25. ADuM3190 SN1 Scope A, Run # 169, Frame # 068

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Figures 3-26 and 3-27 show transients on REF_{OUT} (REF2 on the scope plot).

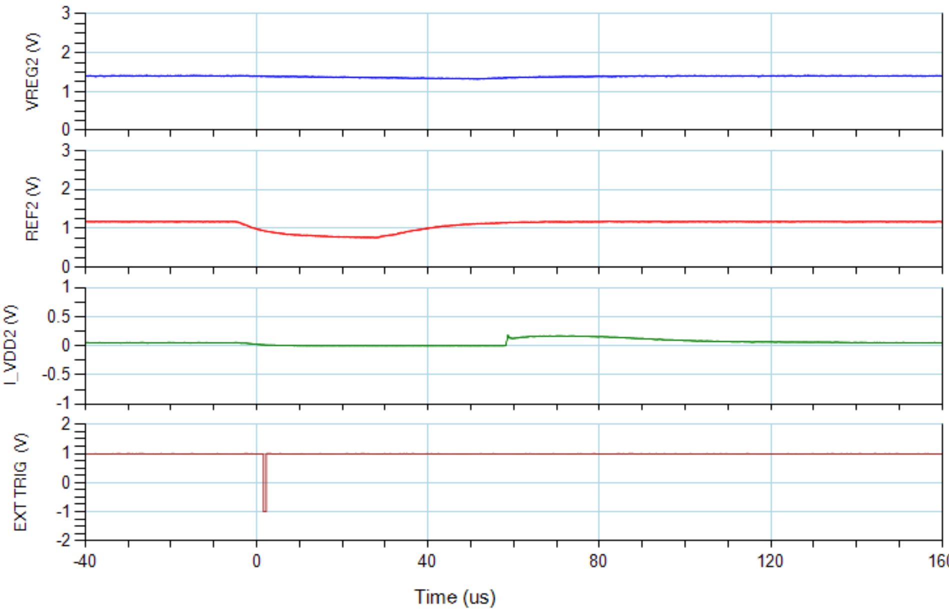

Figure 3-26. ADuM3190 SN3 Scope B, Run # 175, Frame # 001

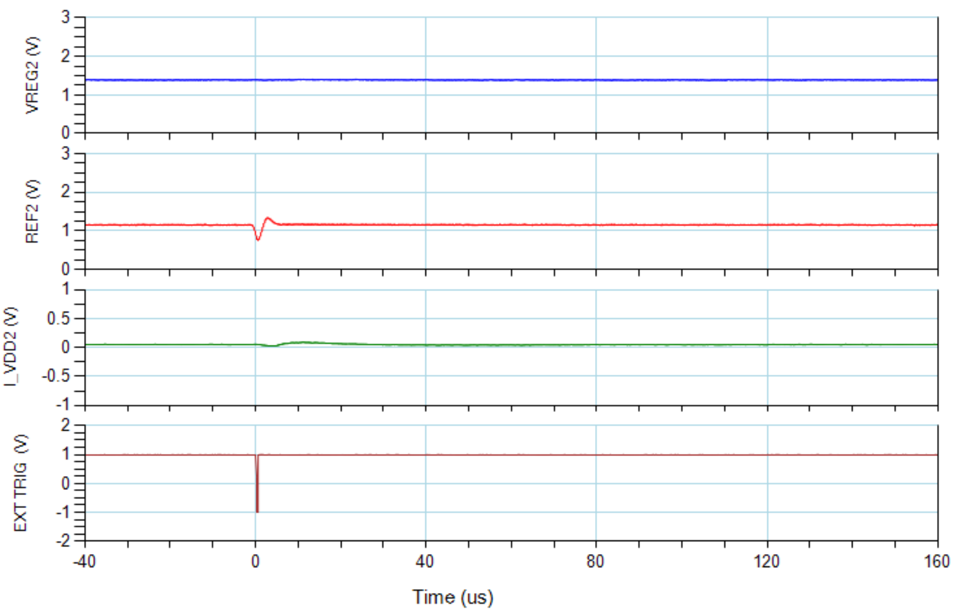

Figure 3-27. ADuM3190 SN1 Scope B, Run # 177, Frame # 012

4. Summary and Conclusions

Six (6) units of the ADuM3190 High Stability Isolated Error Amplifier were tested for Single Event Effects (SEE) with heavy ion irradiation on 13 July 2017 and 24 August 2017 in air and at ambient room temperature at the Cyclotron Institute at Texas A&M University using the K500 Cyclotron and the 15 MeV/n beam.

SEL Summary

The ADuM3190 did not latch-up or burnout at a LET of 59 MeV-cm^2/mg with no differential voltage across the isolation barrier. The ADuM3190 underwent a destructive event at a LET of 78 MeV-cm^2/mg with no differential voltage across the isolation barrier.

SET Summary

Transients on EA_OUT, EA_OUT2, REF_OUT, and REF_OUT1 with magnitudes up to the rail voltage and durations of a few microseconds to 50 microseconds were observed from LETs of 2.7 to 78 MeV-cm^2/mg.

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Appendix A: Photographs of Sample Device-Under-Test

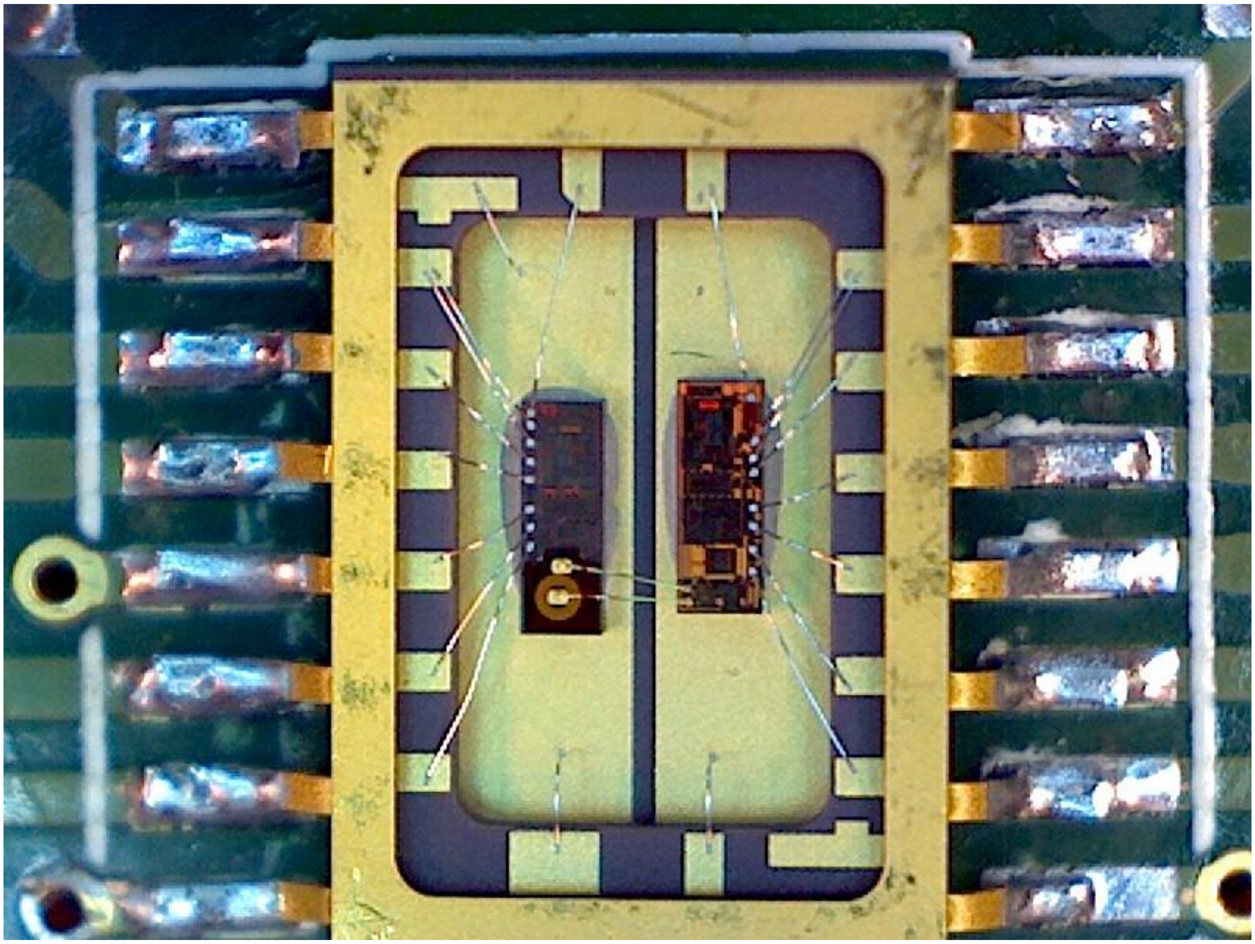

Figure A-1. ADuM3190 as Supplied by the Customer

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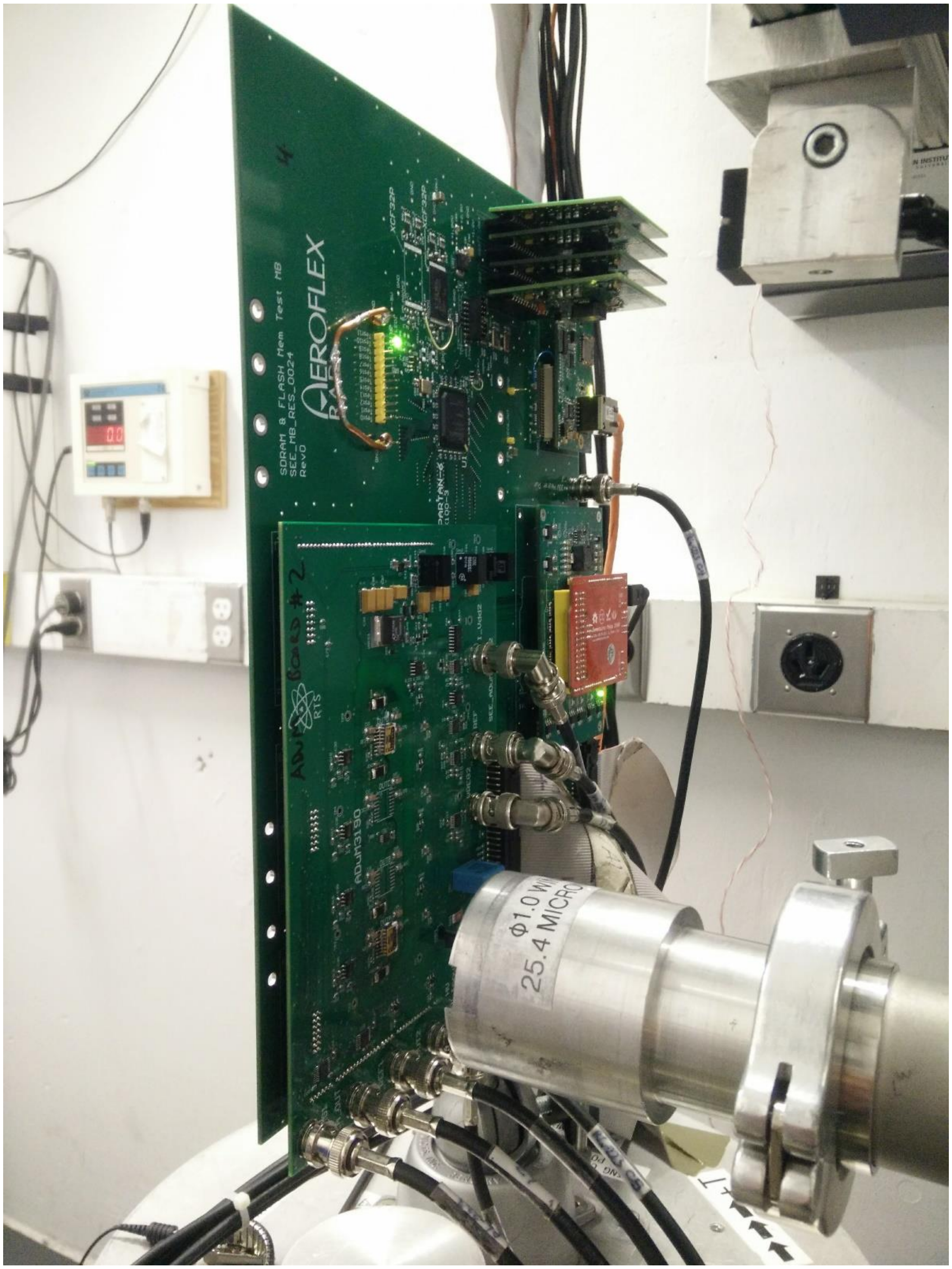
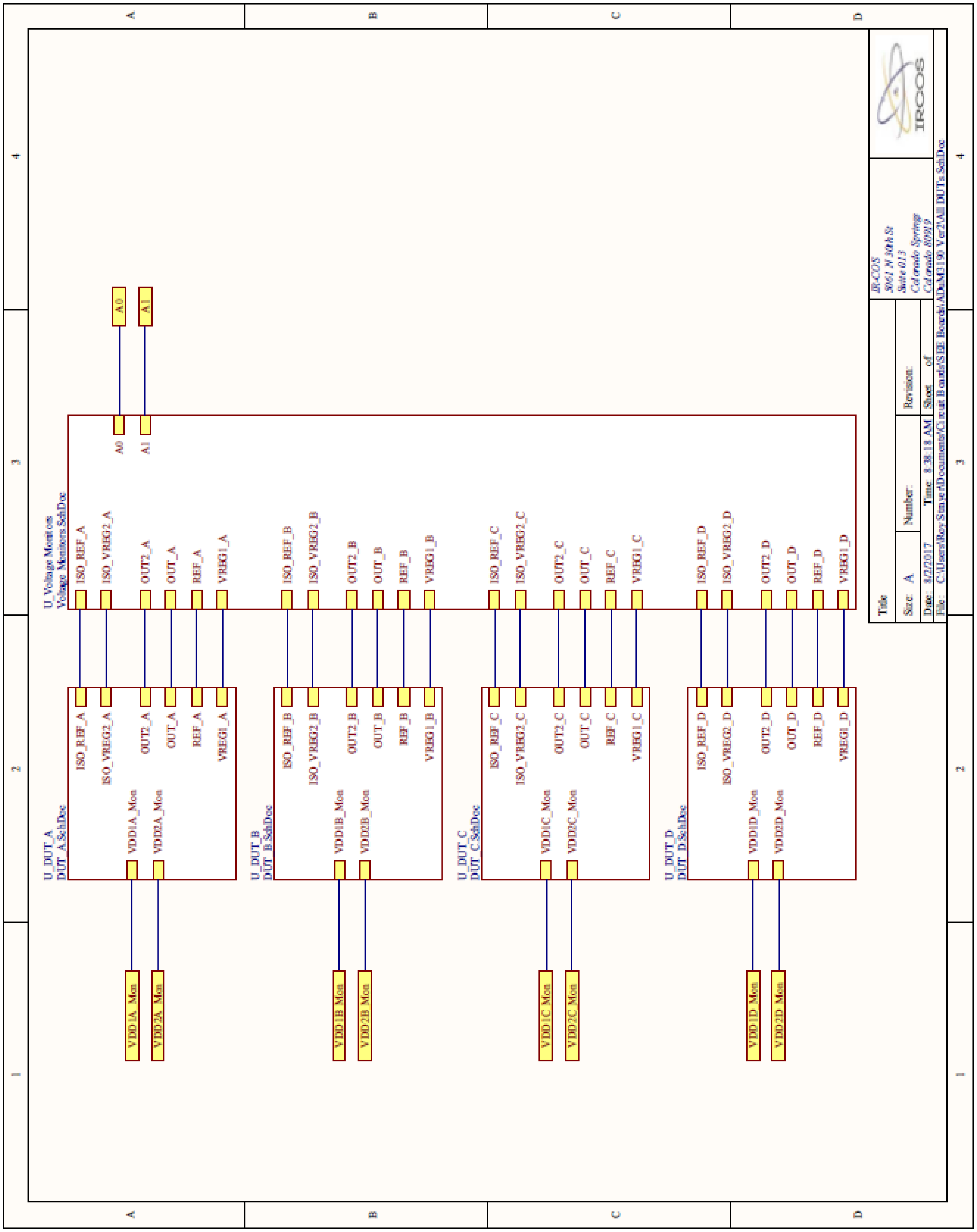


Figure A-2. ADuM3190 Test Setup

Appendix B: Schematics



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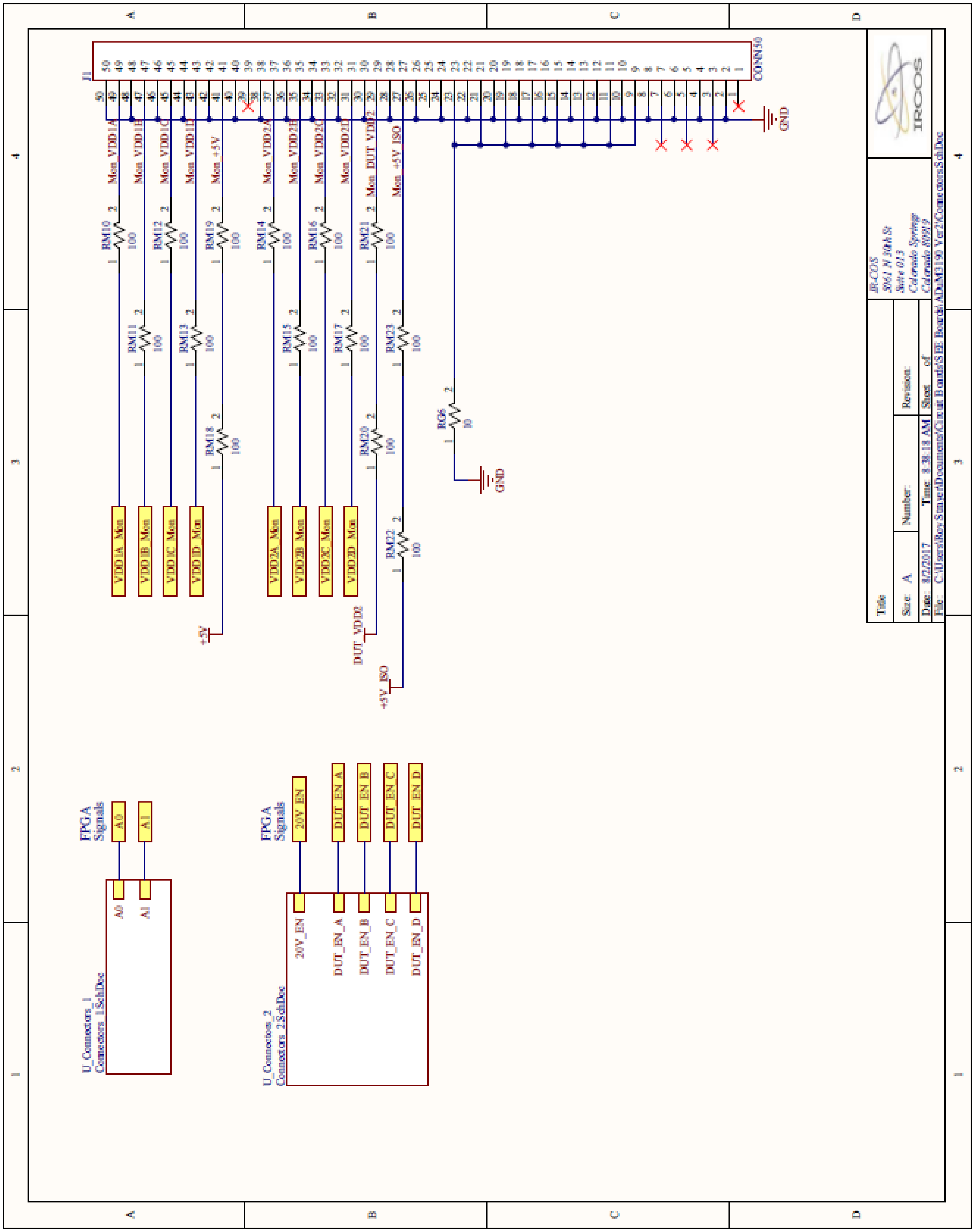

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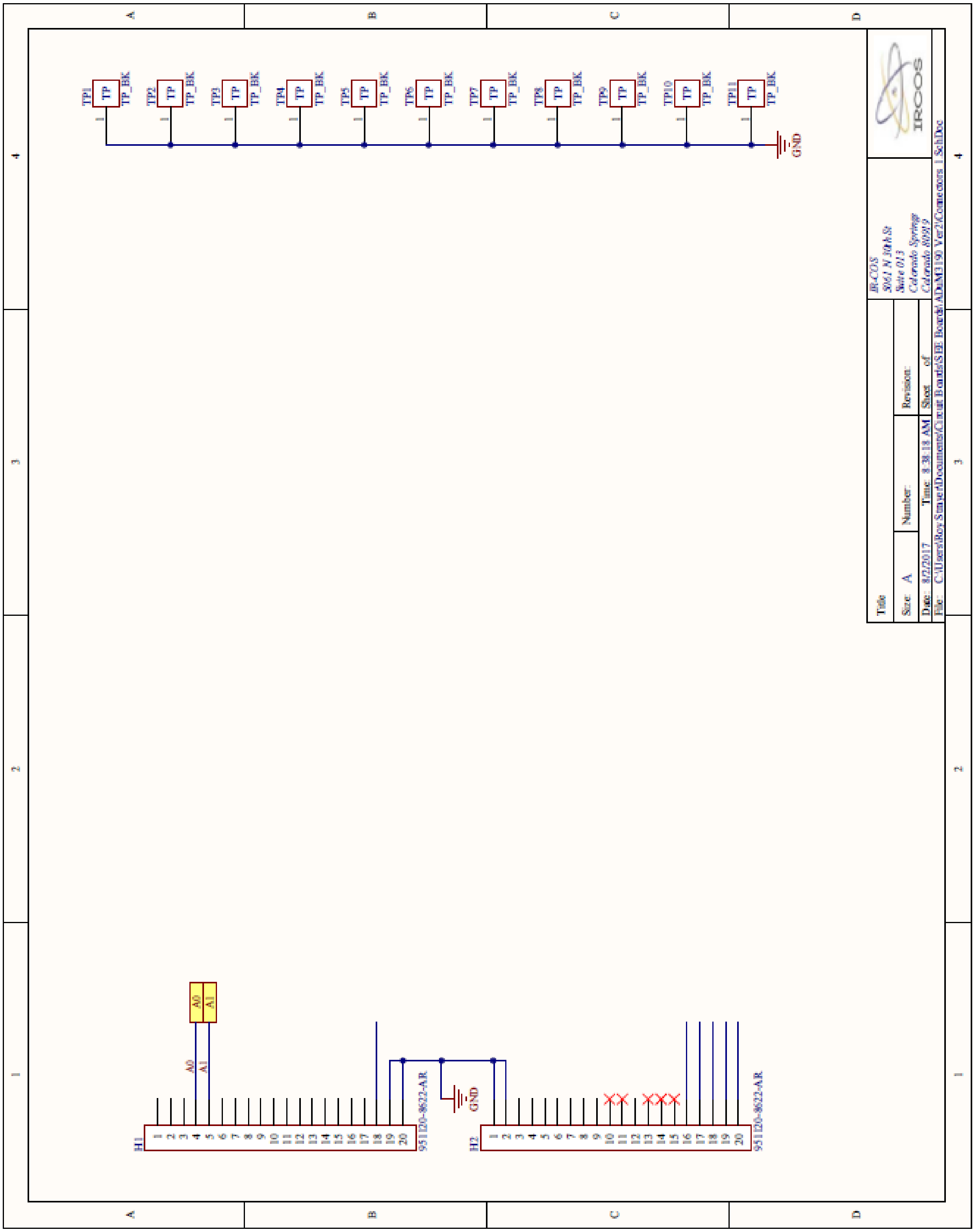

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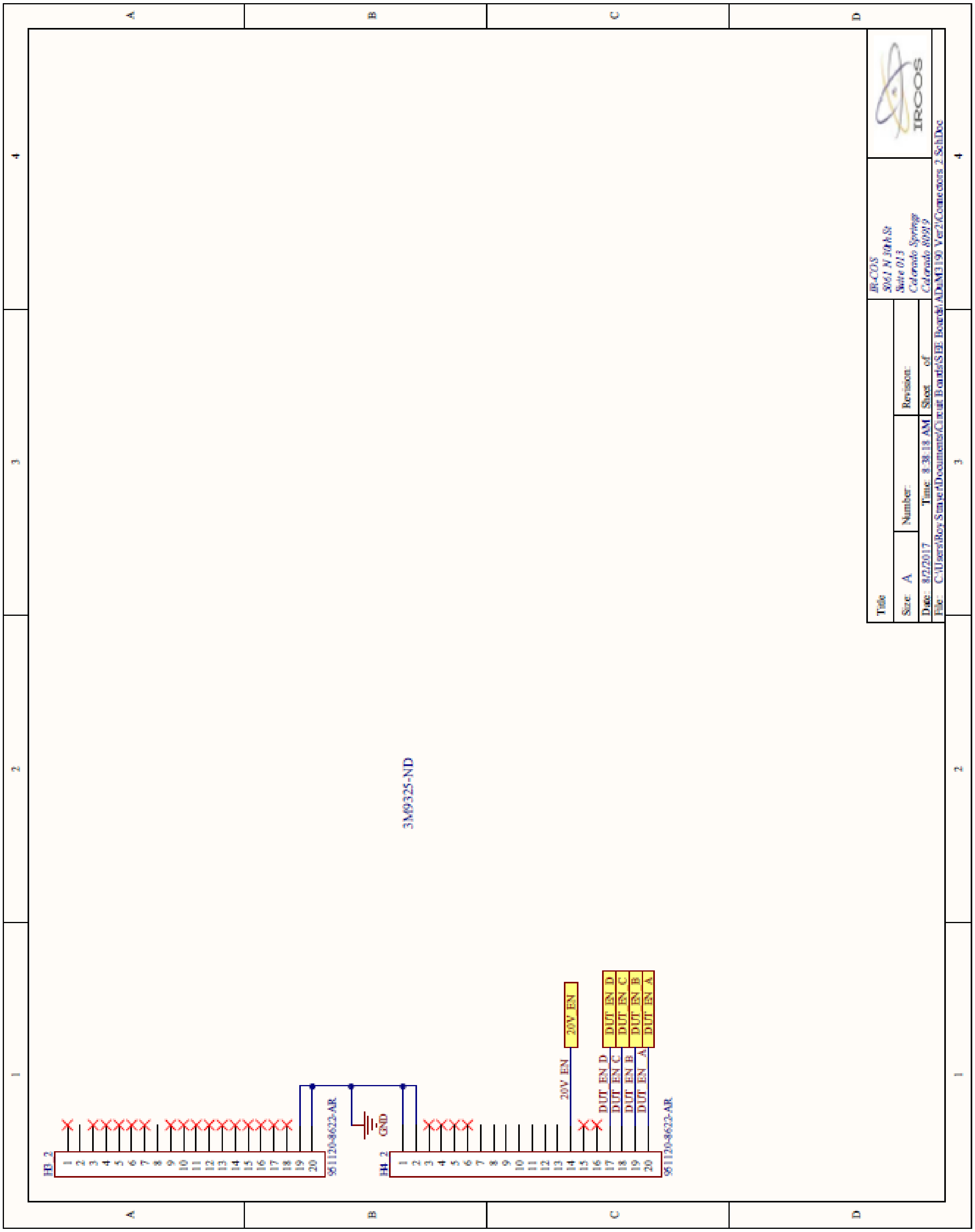

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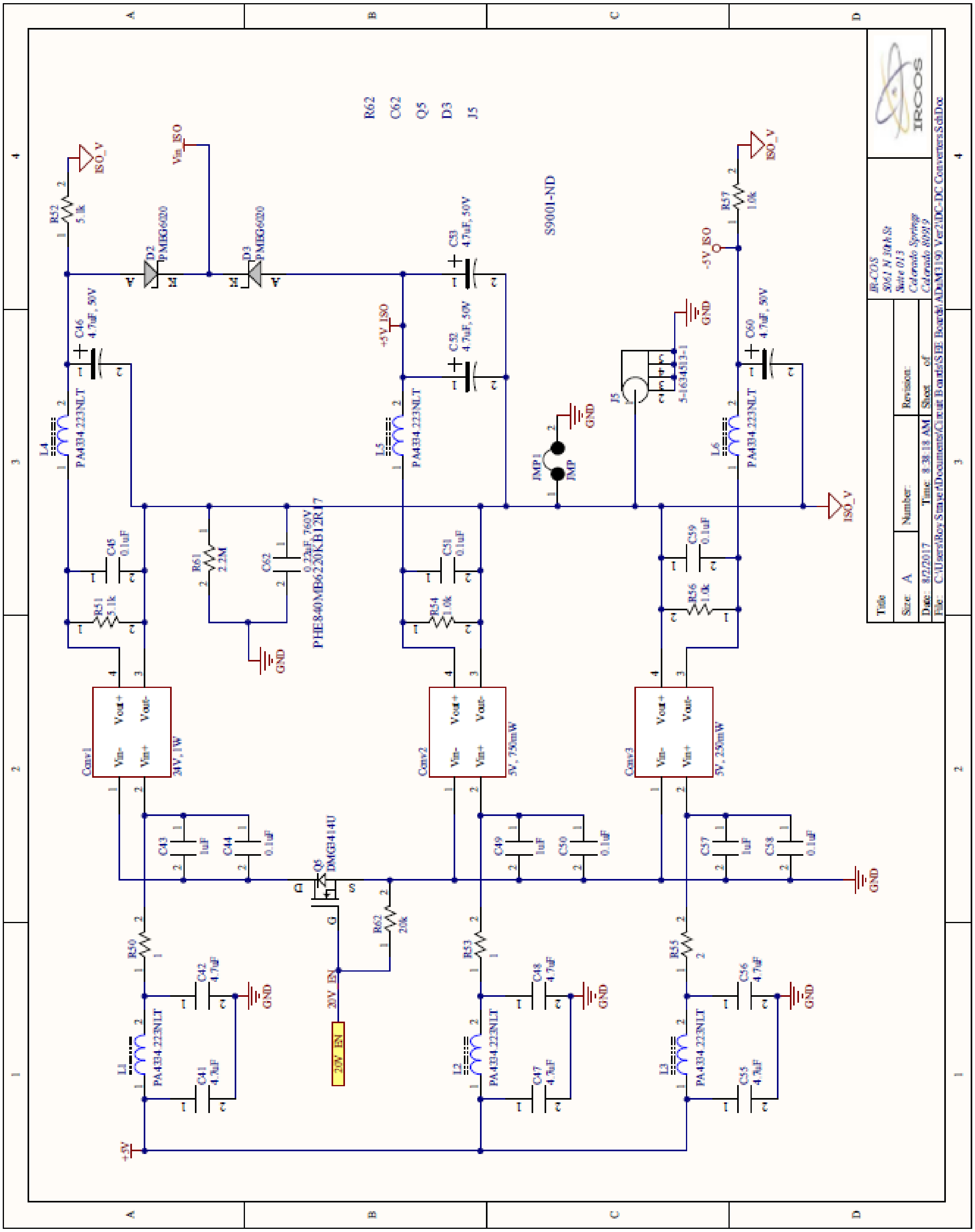

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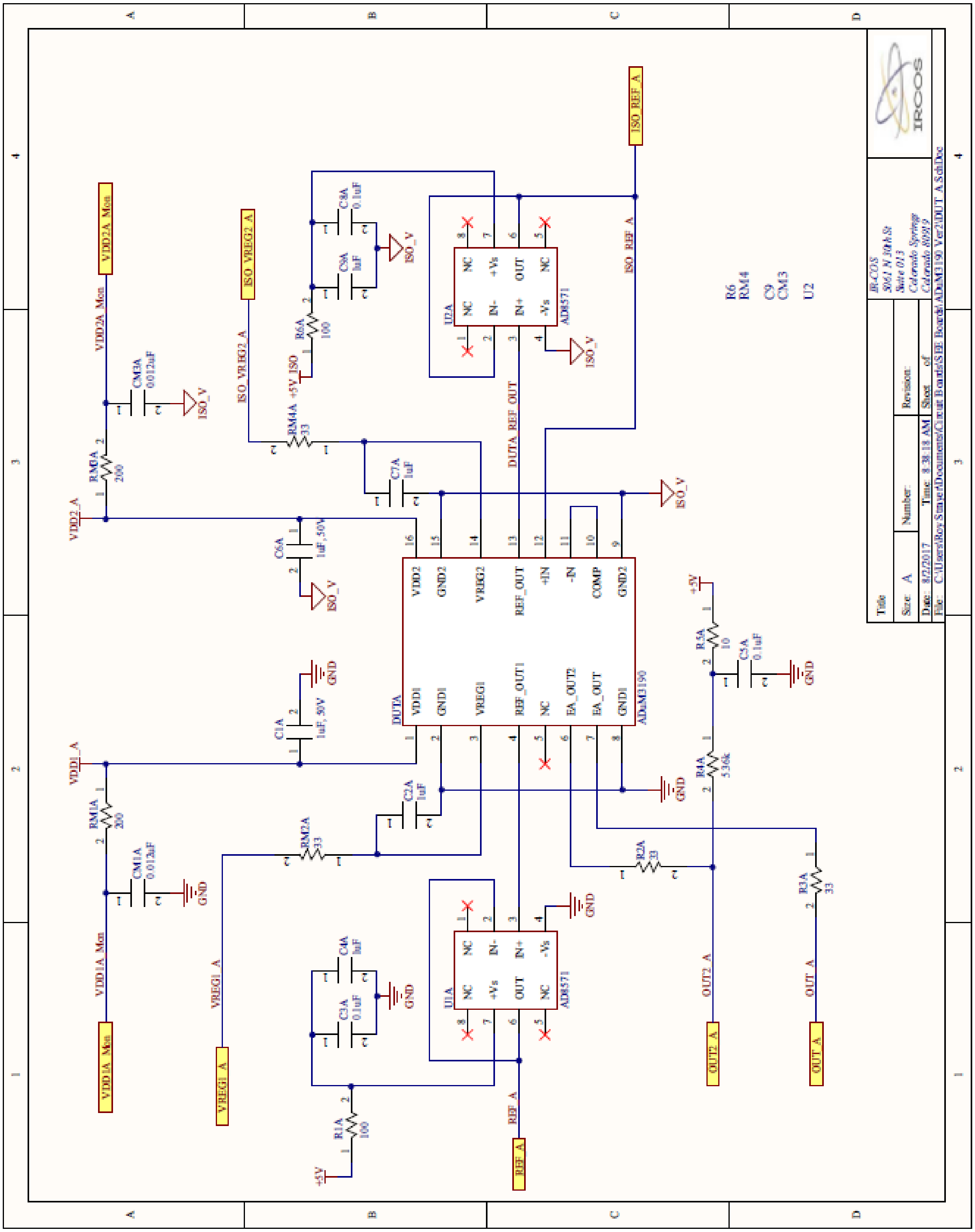

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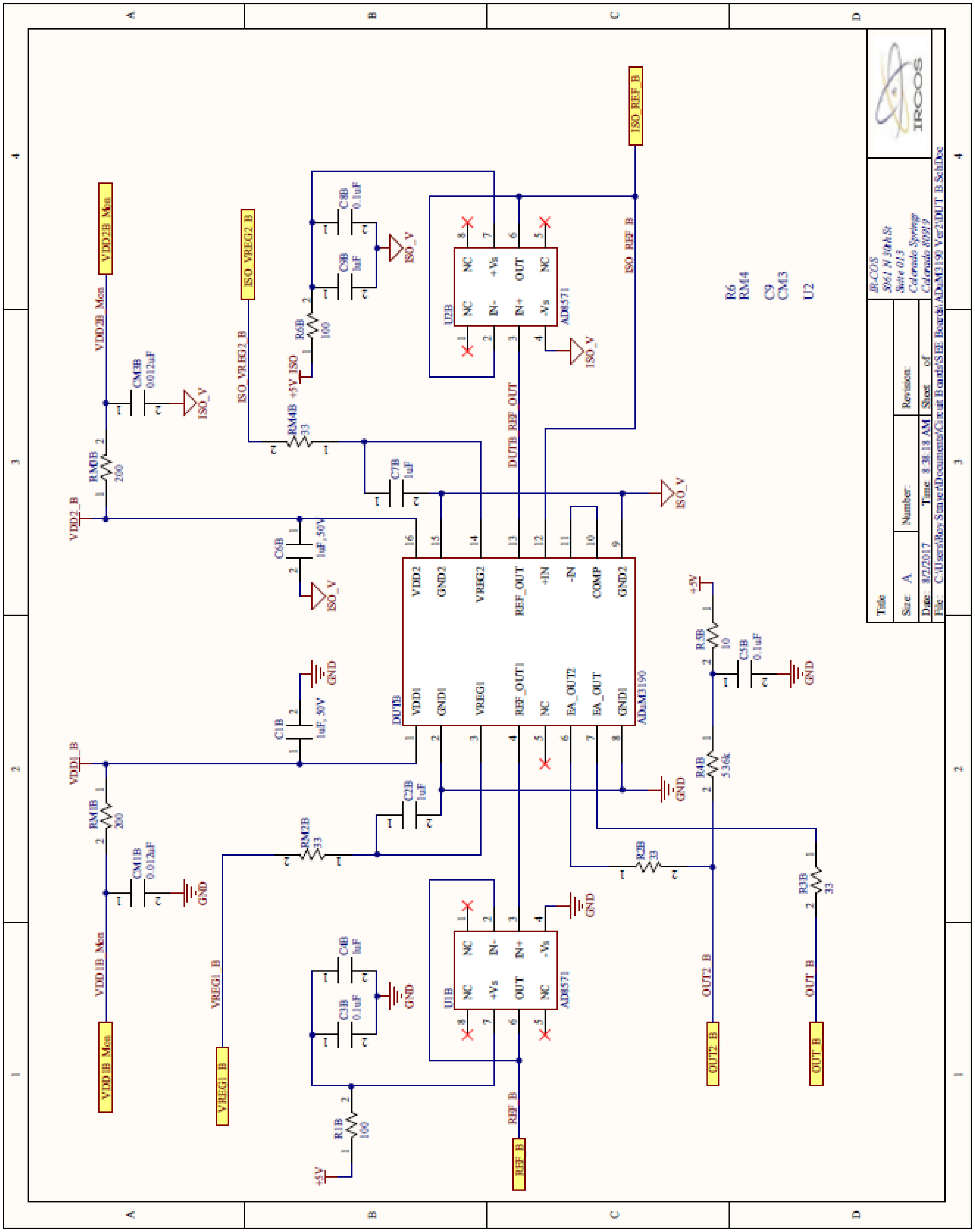

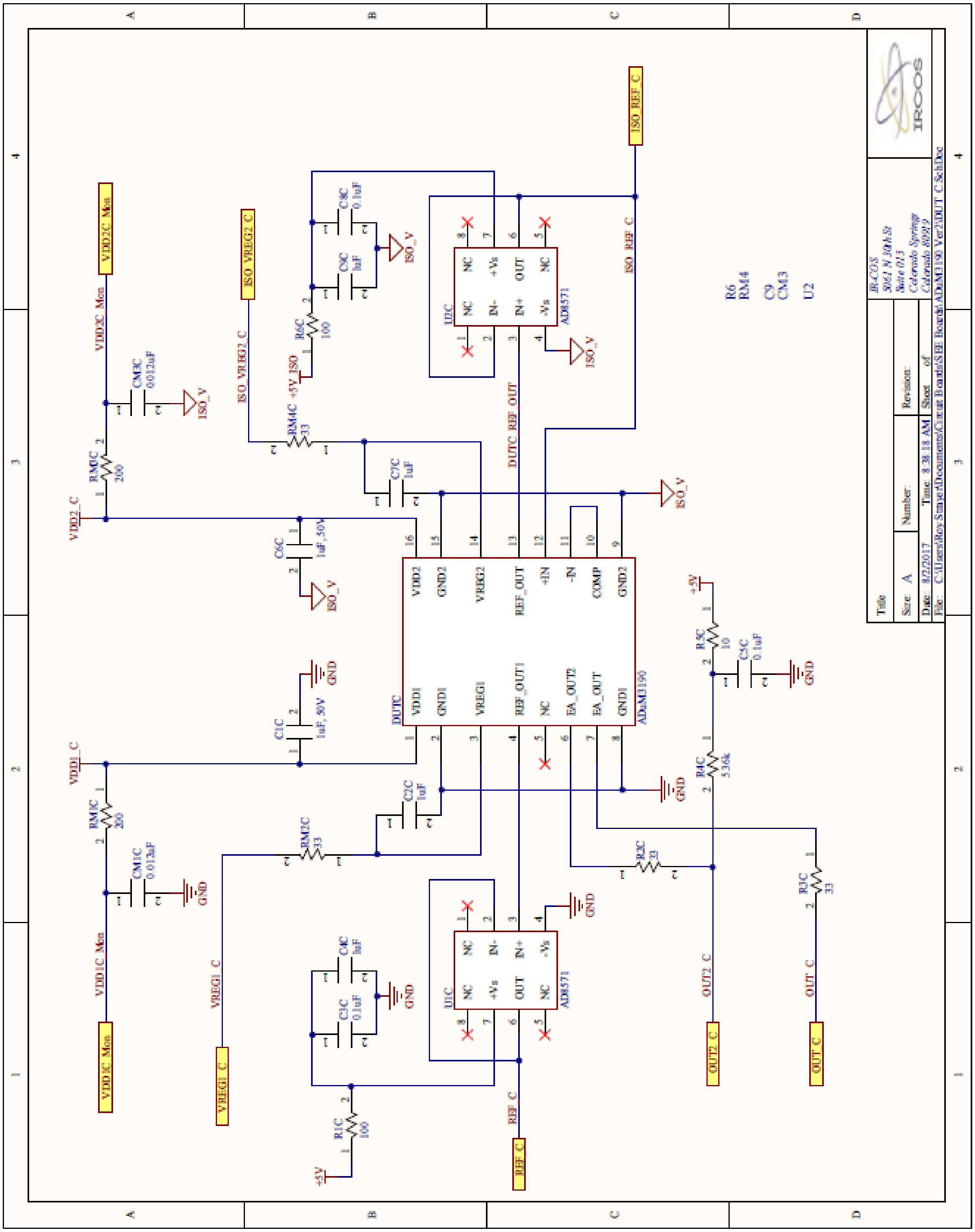
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ISO_VREG2_C
VDD1C_Mon
VREG1_C
REF_C
OUT2_C
OUT_C
DUTC
ADuM3190
U1C
U2C
AD8571

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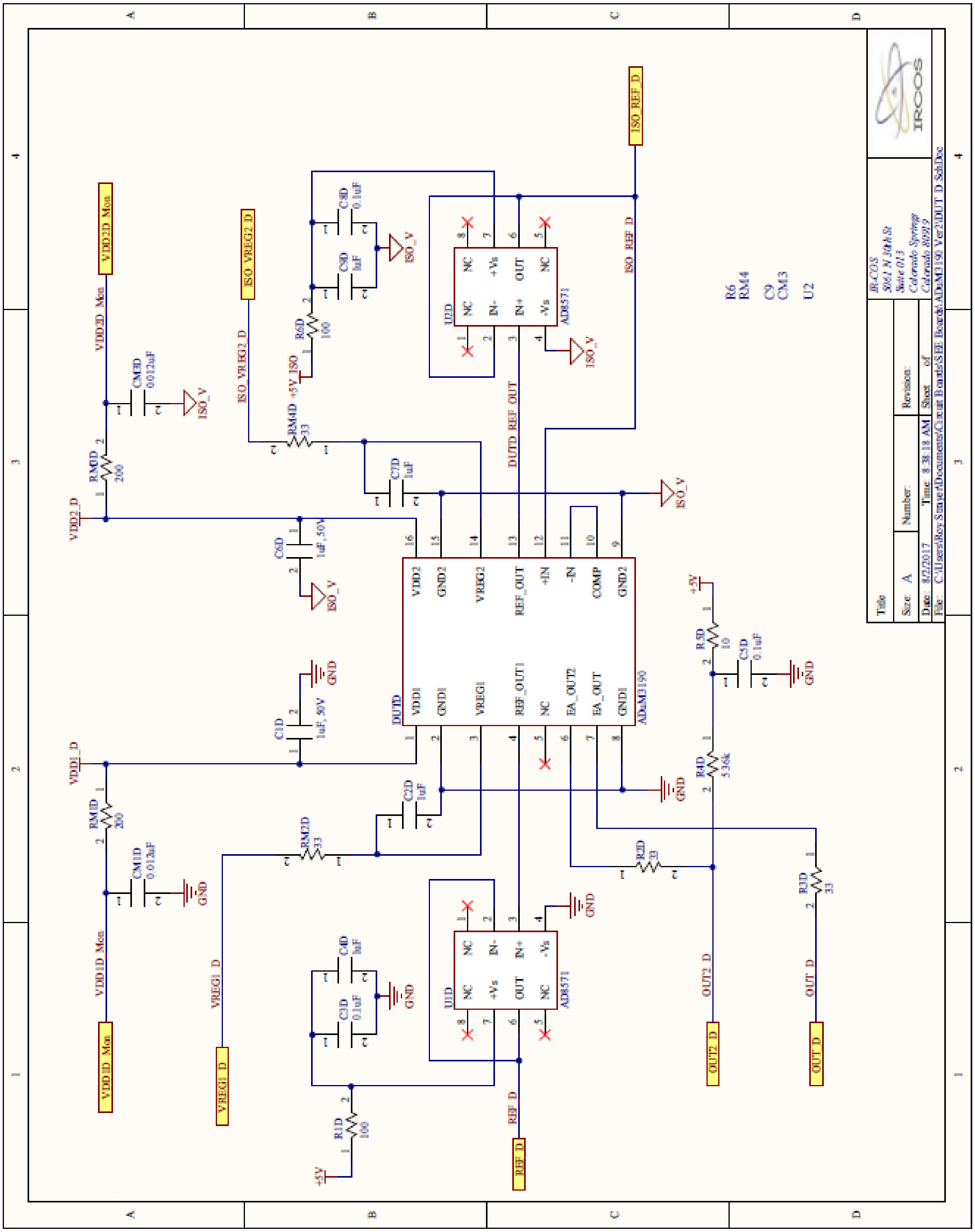

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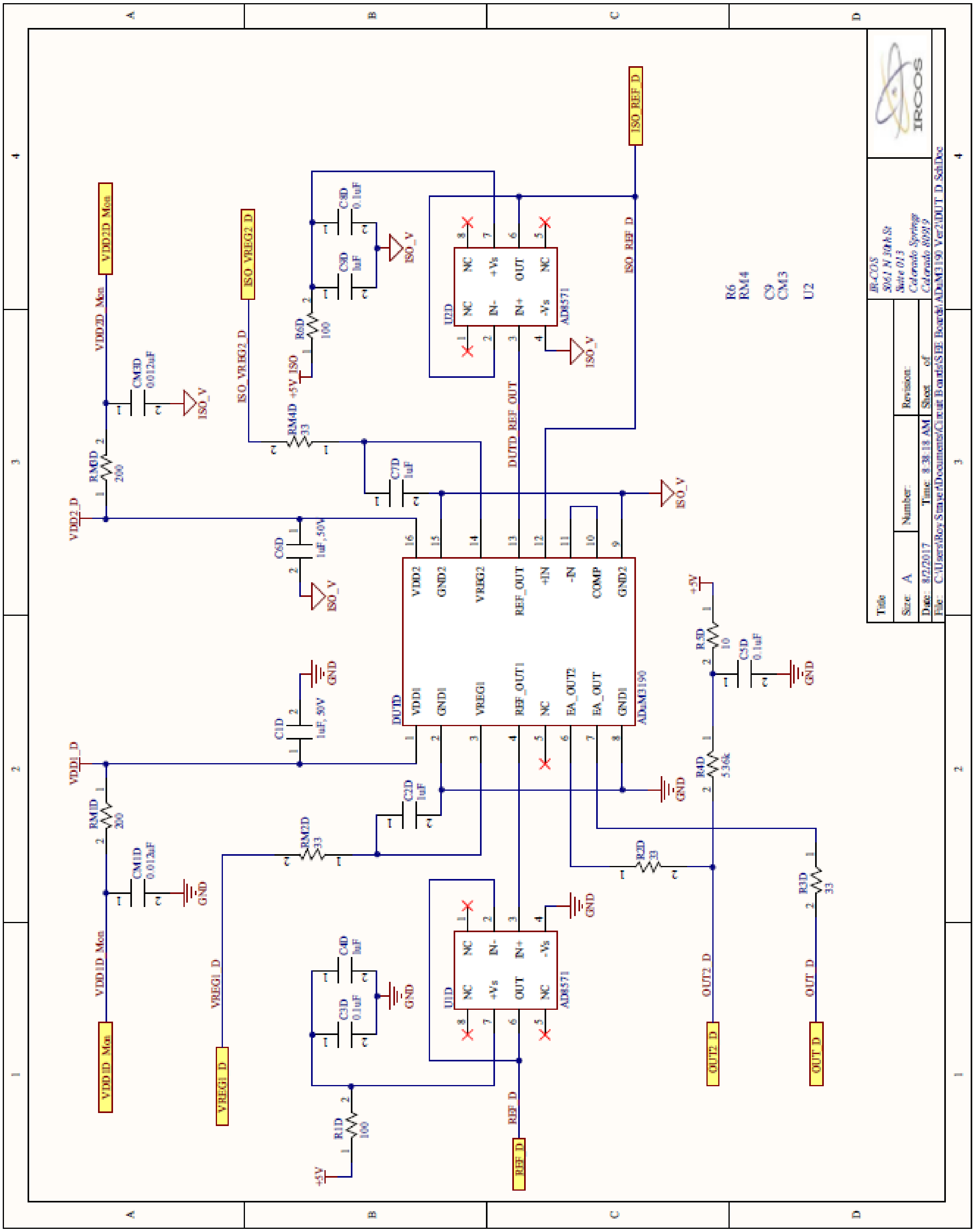

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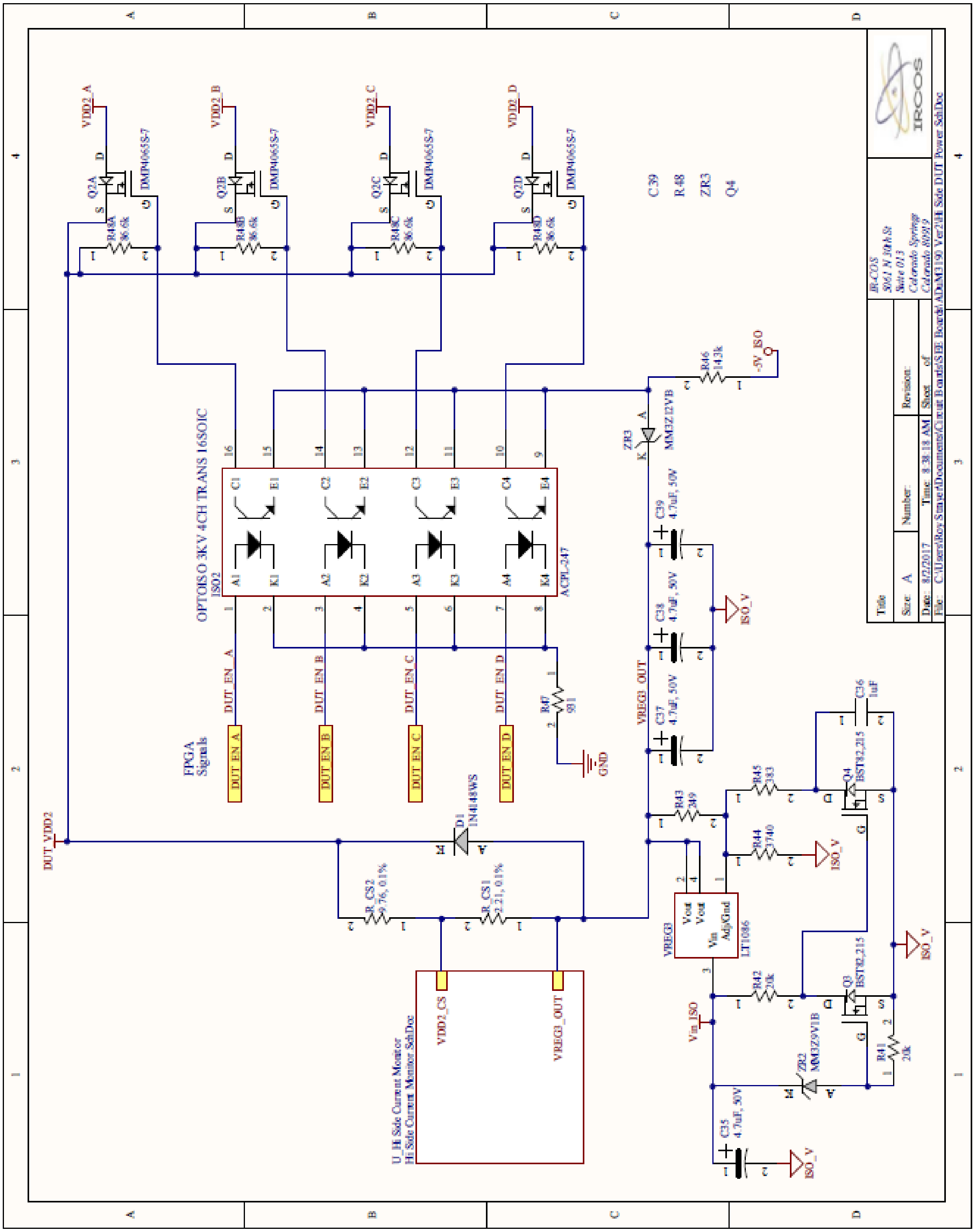

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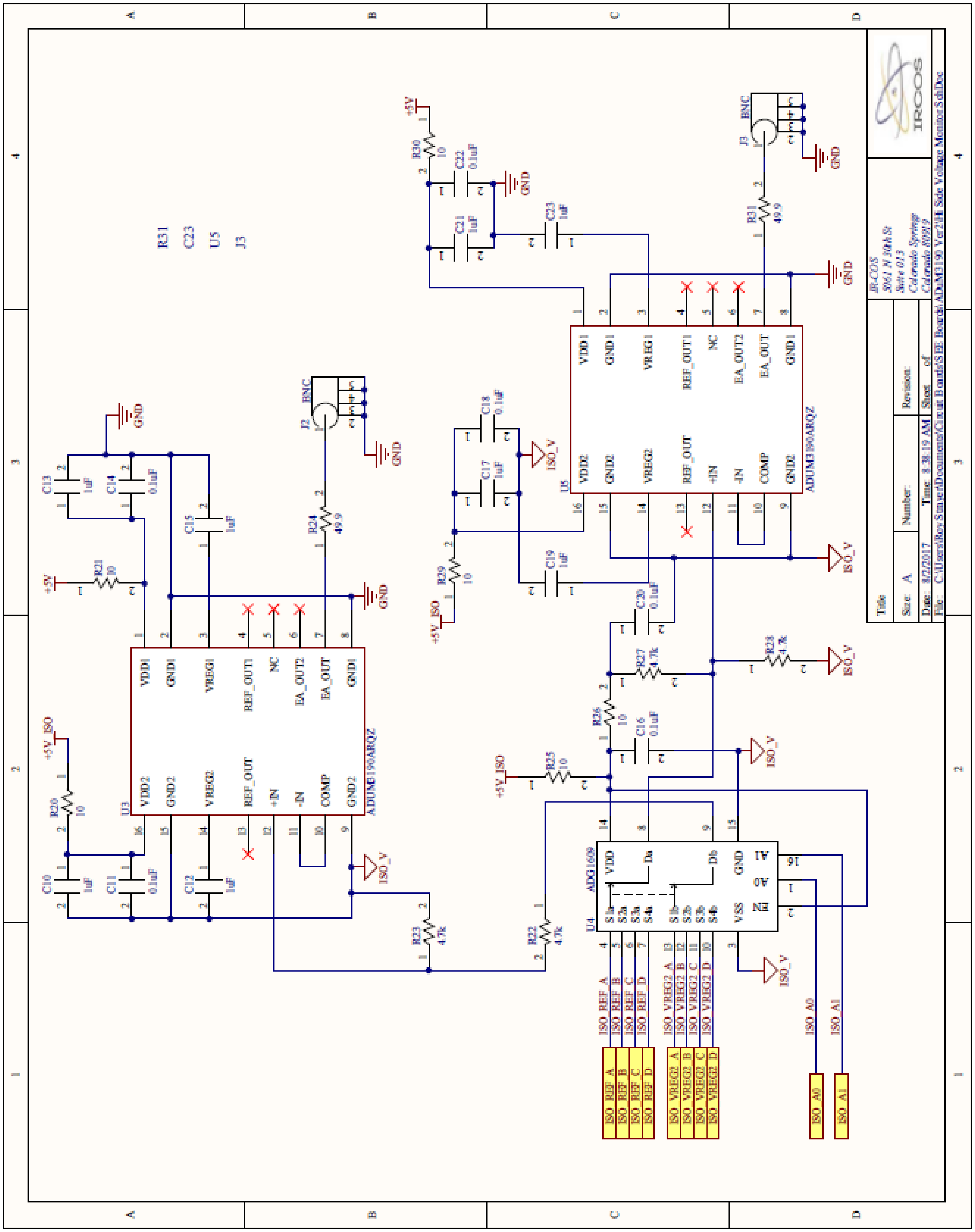
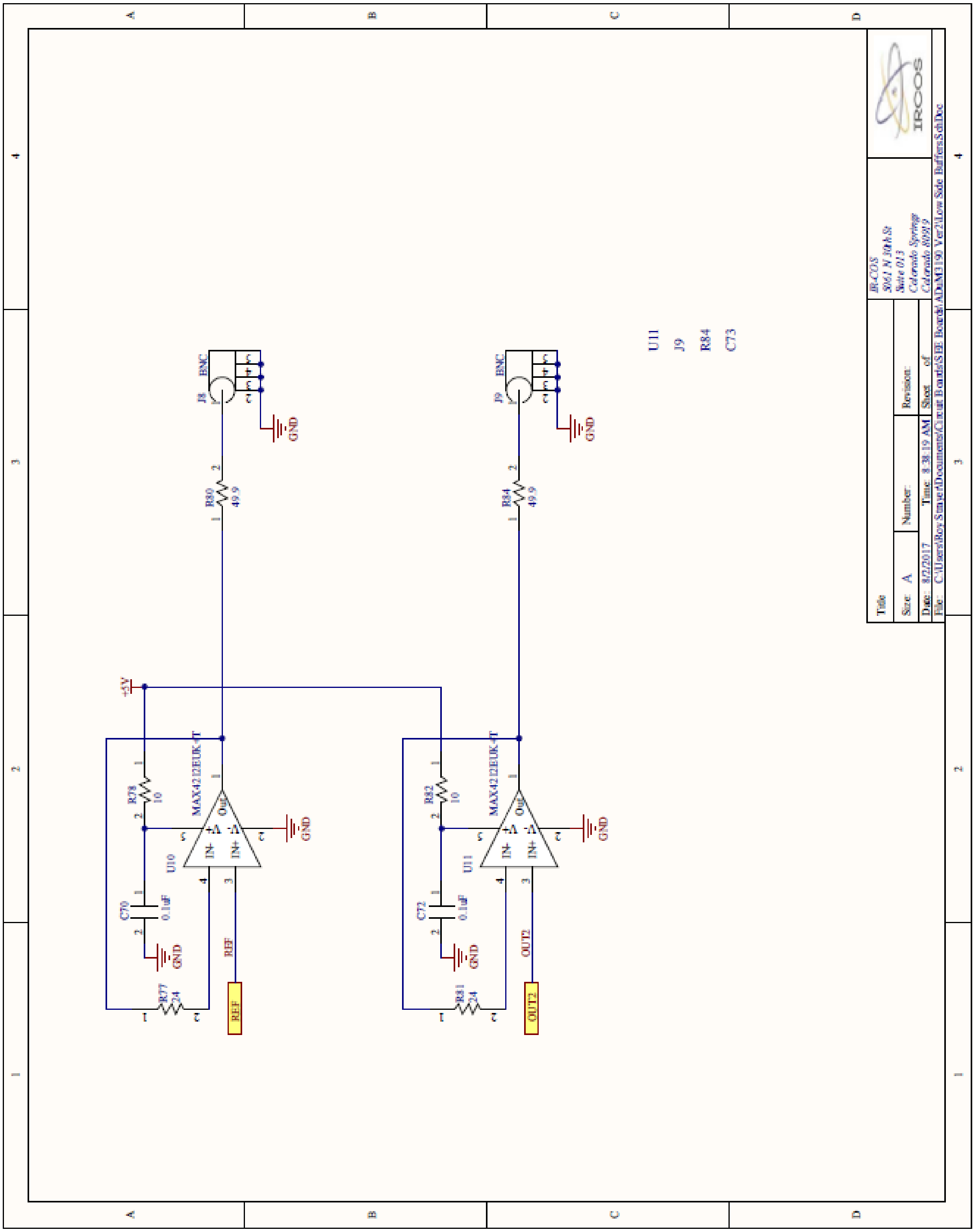
Test Report for SEE Testing of the ADuM3190 High Stability Isolated Error Amplifier




U11
J9
R84
C73
BNC
GND
MAX4212EUK-T
REF
OUT2
+5V

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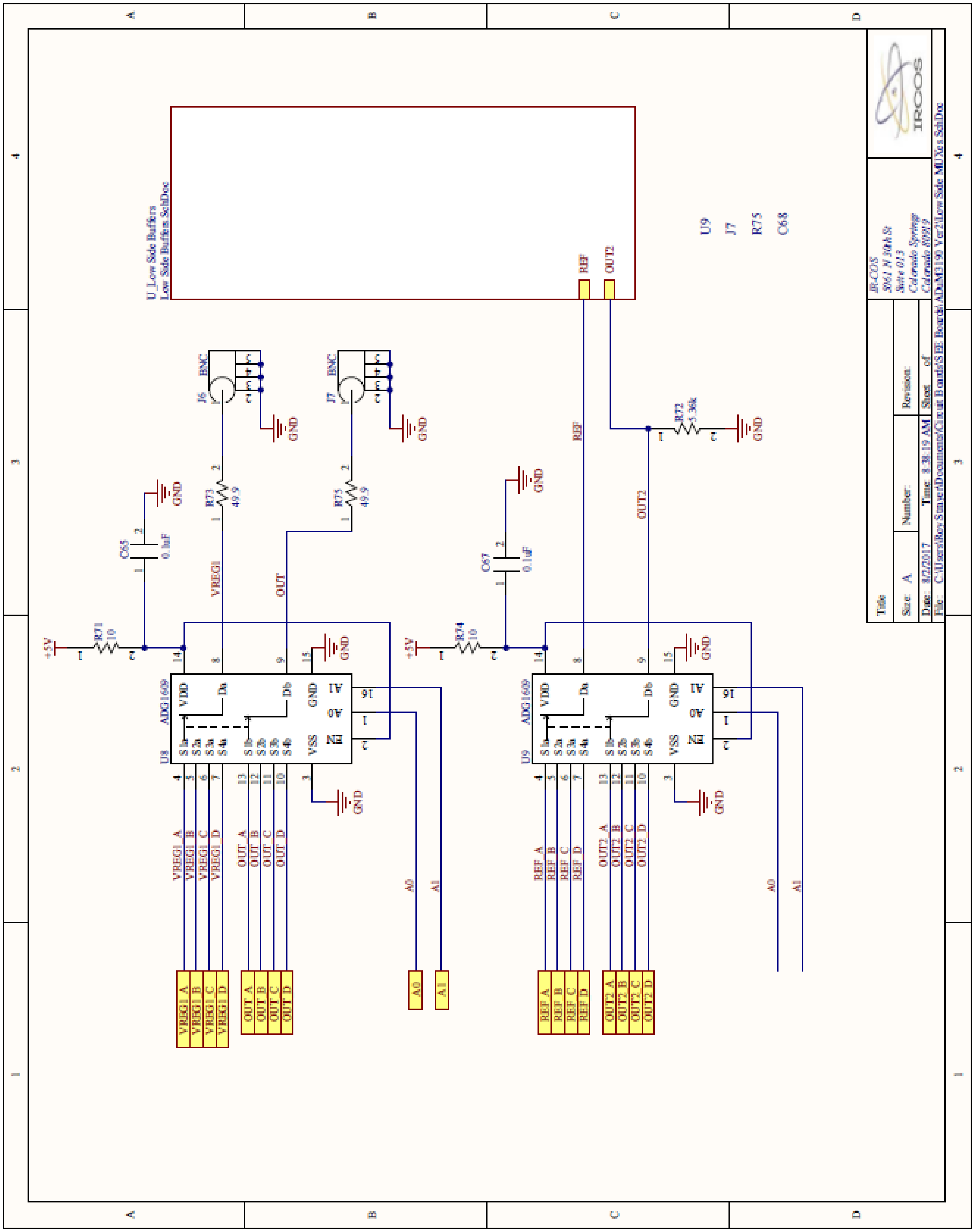

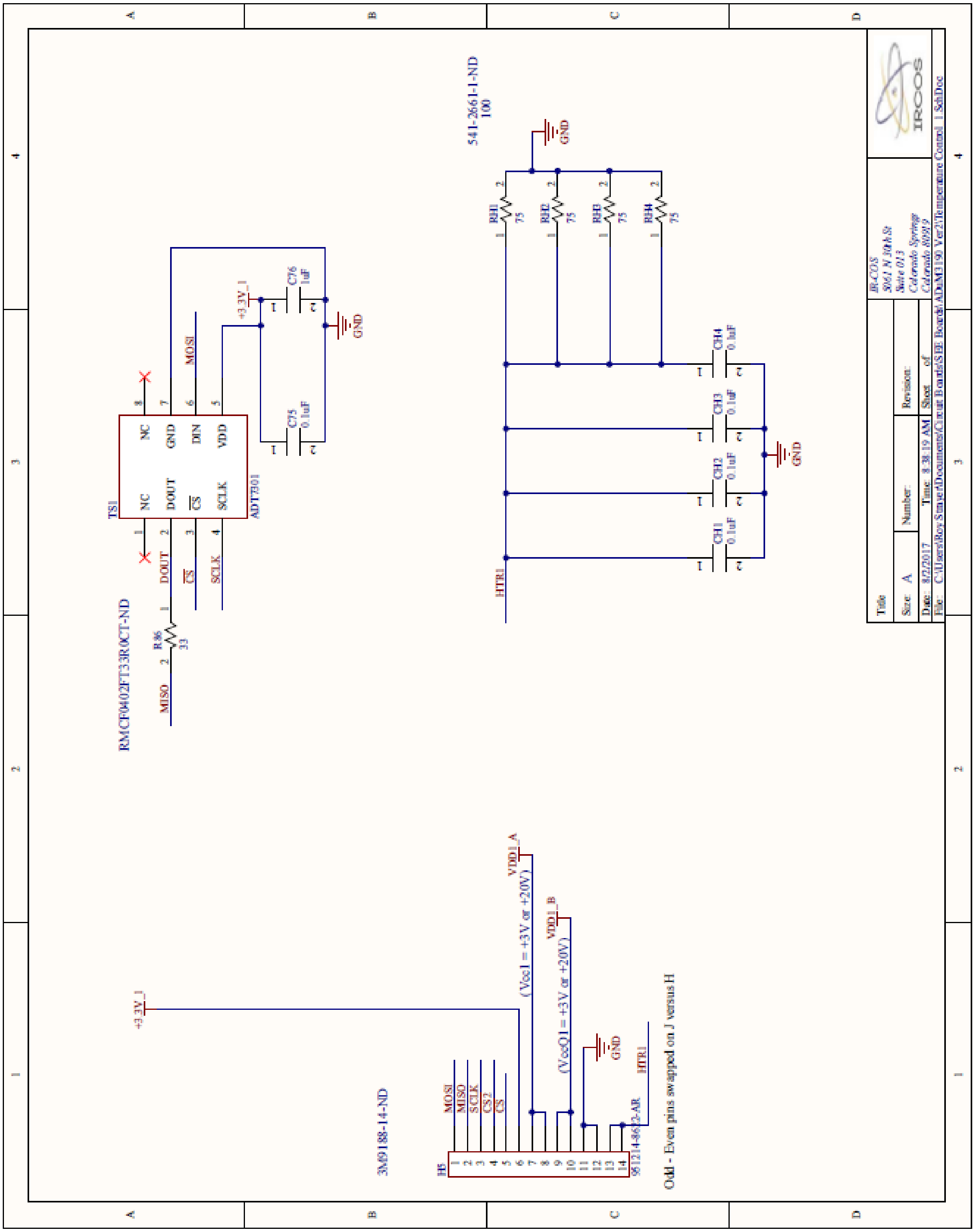

541-2661-1-ND
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RH2
RH3
RH4
75
GND
CH1
CH2
CH3
CH4
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HTR1
TS1
ADT7301
NC
GND
DIN
VDD
DOUT
SCLK
MOSI
MISO
C75
C76
1uF
+3.3V_1
R86
33
RMCF0402FT33R0CT-ND
VDD1_A
VDD1_B
(Vcc1 = +3V or +20V)
(VccO1 = +3V or +20V)
3M9188-14-ND
H5
95121-8612-AR
Odd - Even pins swapped on J versus H
IRCOS

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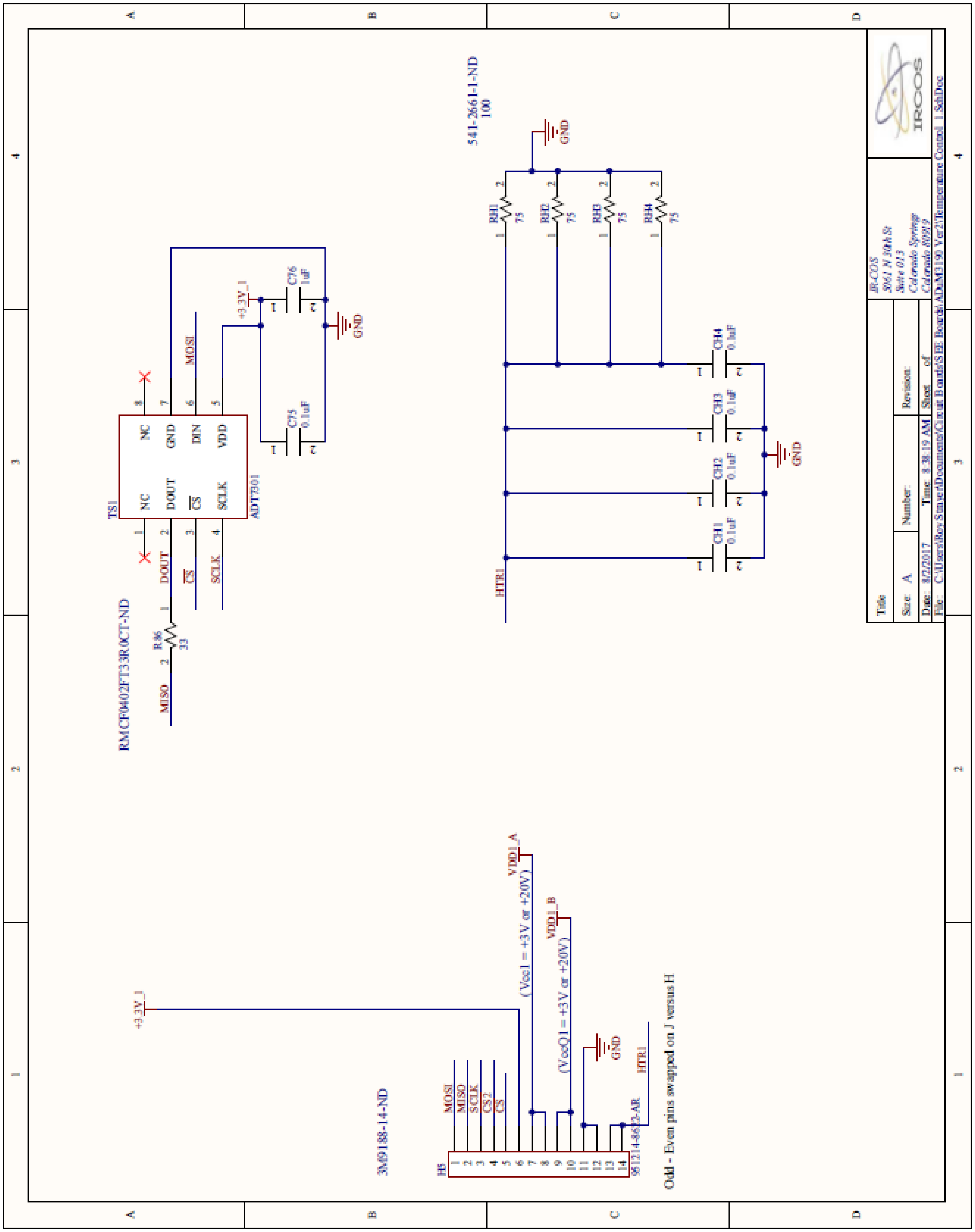

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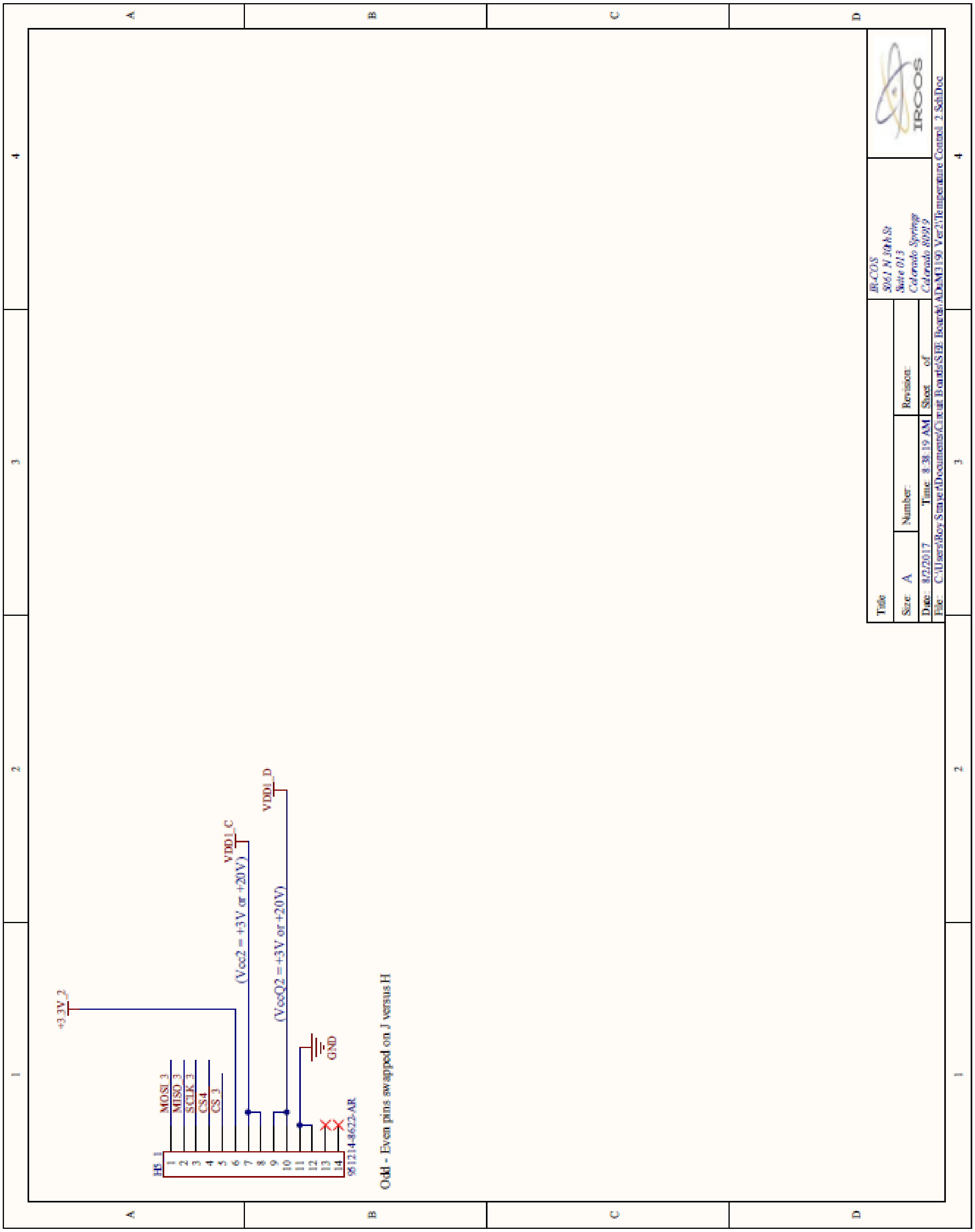

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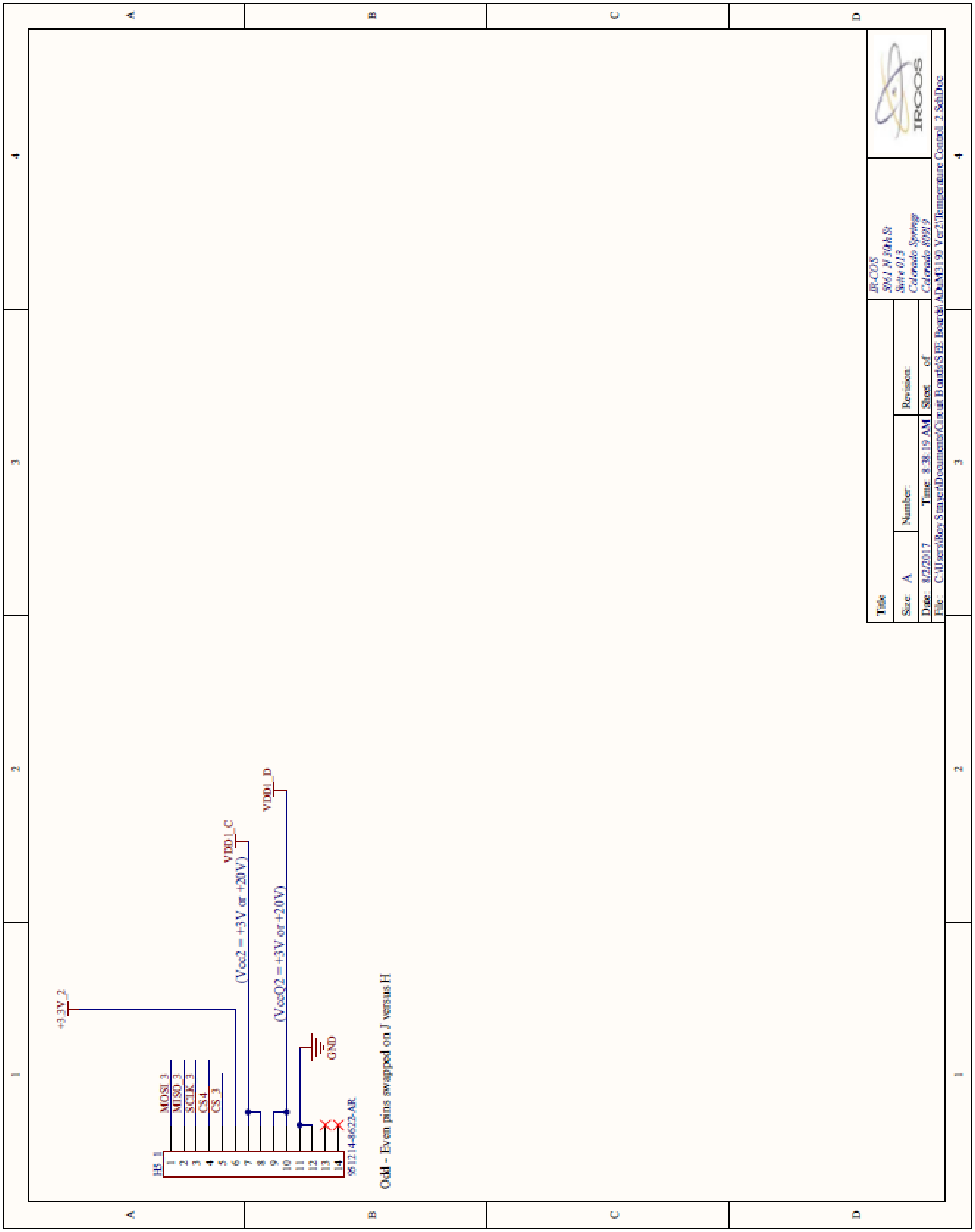

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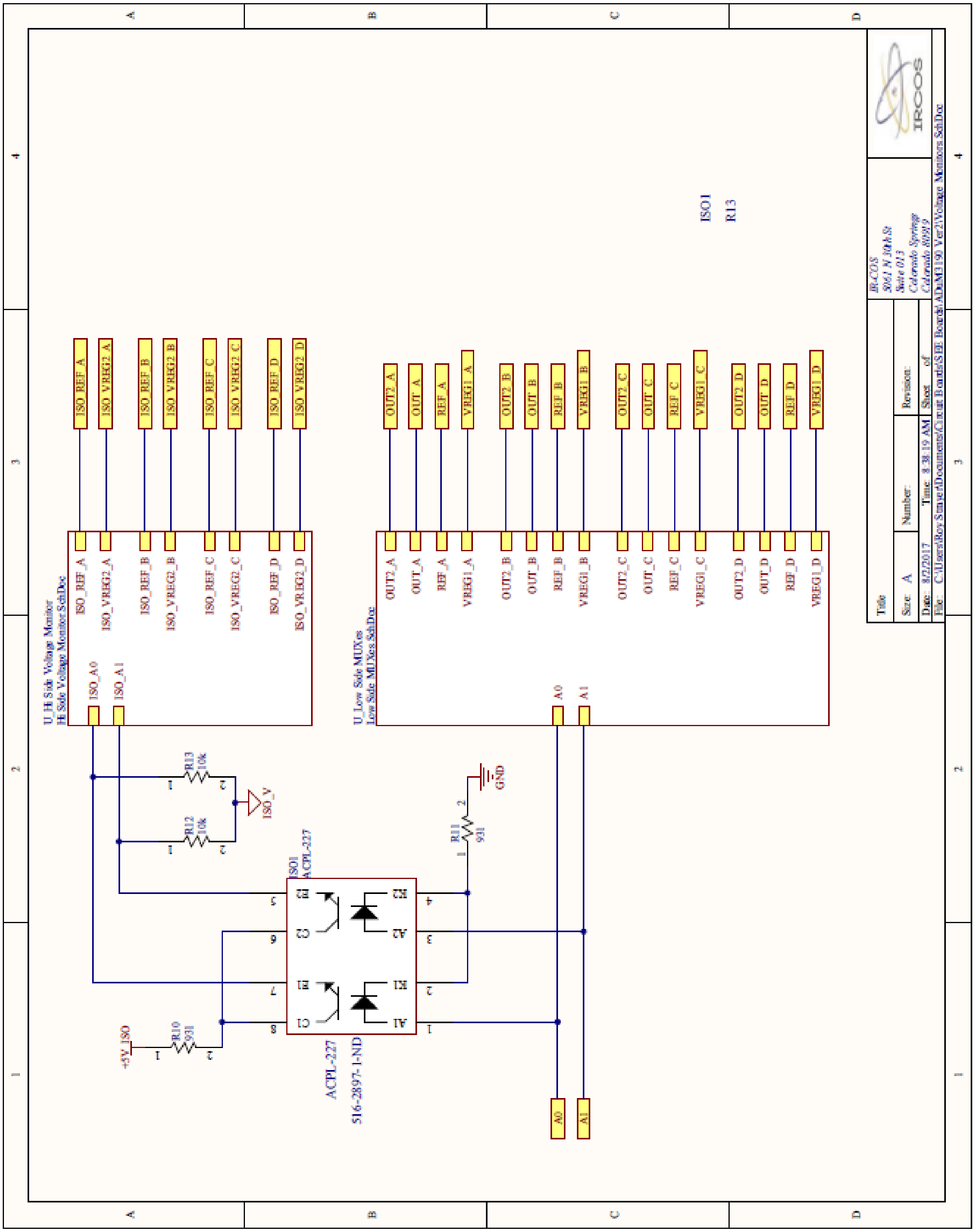

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Appendix C: Equipment List

Table C-1 lists the equipment typically used during the testing as well as the calibration dates and the date the calibration is due.

Table C-1. Test Equipment List and Calibration Dates.

Equipment	Entity Number	Calibration Date	Calibration Due
Keithley 2420 Source Meter	TS27	04/06/2017	04/06/2018
Keithley 2420 Source Meter	TS28	06/27/2017	06/27/2018
Keithley 2410 Source Meter	TS29	04/06/2017	04/06/2018
Agilent 34970A Data Acquisition Unit	DA01	07/20/2017	07/20/2018
Agilent 34901A Multiplexer	MP01	07/20/2017	07/20/2018
PicoScope 6404D Oscilloscope	OS13	03/23/2017	03/23/2018
PicoScope 6404D Oscilloscope	OS14	05/25/2017	05/25/2018
Fluke 115 True RMS Multimeter	HM12	01/31/2017	01/31/2018
Housekeeping Power Supply		NA	NA

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Appendix D: Single Event Effects Apparatus

The SEE testing described in this test report was performed at the Cyclotron Institute at Texas A&M University (TAMU) using their K500 Cyclotron. The testing was performed in air using the 15 MeV/n beam. The beam characteristics and dosimetry were provided by the TAMU heavy ion test facility.

TAMU delivers 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/cm2/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.

Table D-1 shows the characteristics of the 15 MeV/n beam including initial LET, LET at the Bragg peak and range in silicon as published by TAMU. Figure D-1 shows the LET versus the range in Silicon of the 15 MeV Beams.

Table D-1. Characteristics of the 15 MeV/n beam using the TAMU K500 Cyclotron as published by TAMU.

	Ion	Mass (amu)	A MeV	Total Energy (MeV)	Energy at Bragg Peak (MeV)	Range in Si (μm)	Range at Bragg (μm)	Range to Bragg Peak (μm)	Initial LET (vacuum)	Initial LET (air)	LET at Bragg Peak
15 A MeV	^{4}He	4.003	15	60	0.4	1423	2	1421	0.11	0.11	1.5
	^{14}N	14.003	15	210	7	428	7	421	1.3	1.3	6.7
	^{20}Ne	19.992	15	300	14	316	8	308	2.5	2.6	9.6
	^{40}Ar	39.962	15	599	29	229	9	220	7.7	8.0	20.1
	^{63}Cu	62.930	15	944	90	172	16	156	17.8	18.7	34.0
	^{84}Kr	83.912	15	1259	152	170	21	149	25.4	26.6	41.4
	^{109}Ag	108.905	15	1634	248	156	26	130	38.5	40.3	54.8
	^{129}Xe	128.905	15	1934	339	156	31	124	47.3	49.3	63.4
	^{141}Pr	140.908	15	2114	441	154	37	117	53.8	56.0	69.6
	^{165}Ho	164.930	15	2474	608	156	44	112	64.3	66.7	79.2
	^{181}Ta	180.948	15	2714	702	155	46	109	72.2	74.8	86.4
	^{197}Au	196.967	15	2954	902	155	53	102	80.2	82.8	93.5

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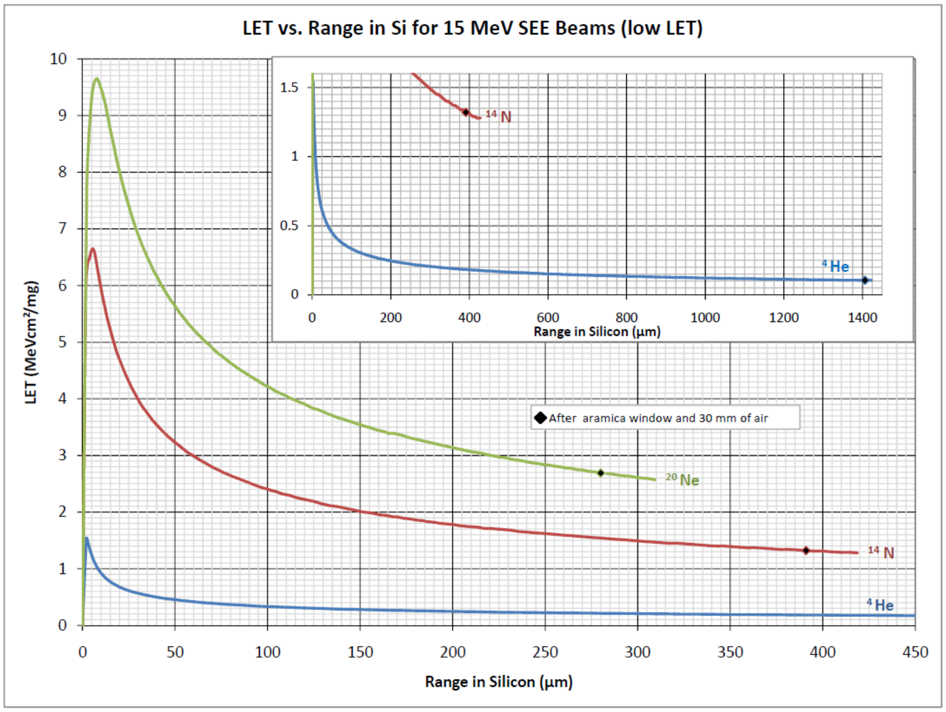

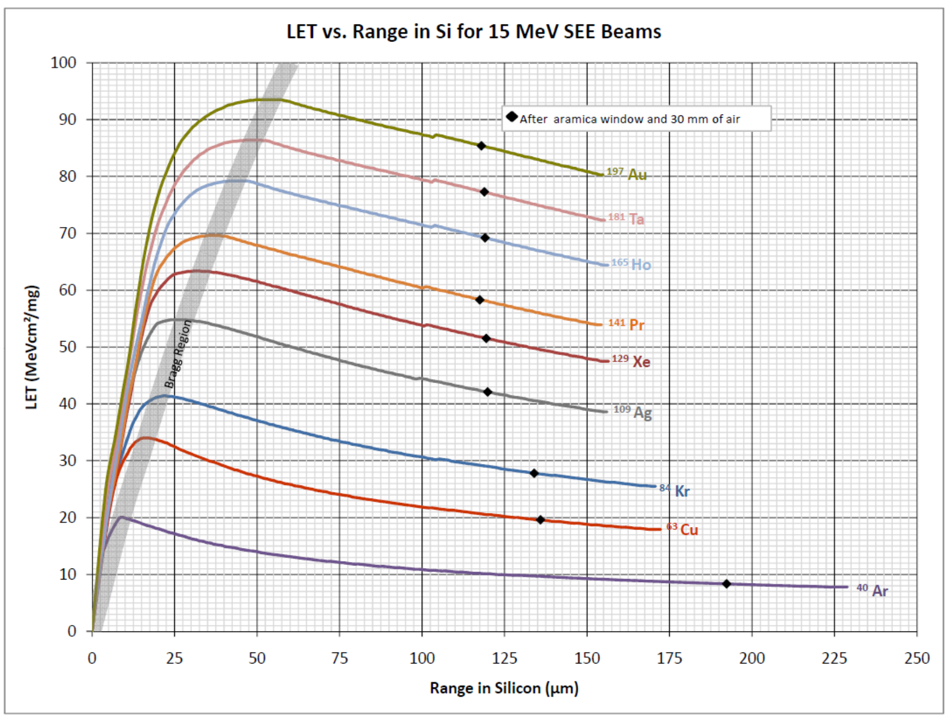

Figure D-1. LET versus Range in Silicon for the 15 MeV SEE Beams

Appendix E: SEL Current and Voltage Plots

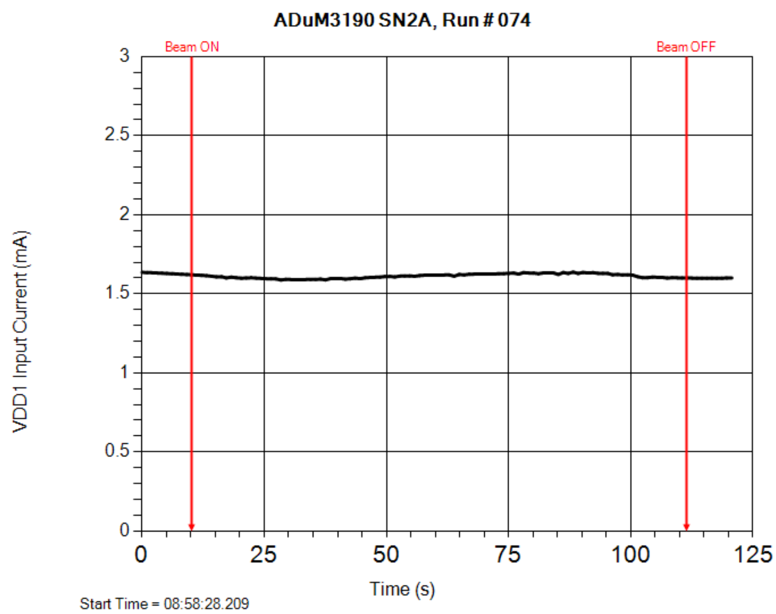

Figure E-1. ADuM3190 SN2A, Run #74, DUT VDD1 Input Current (mA).

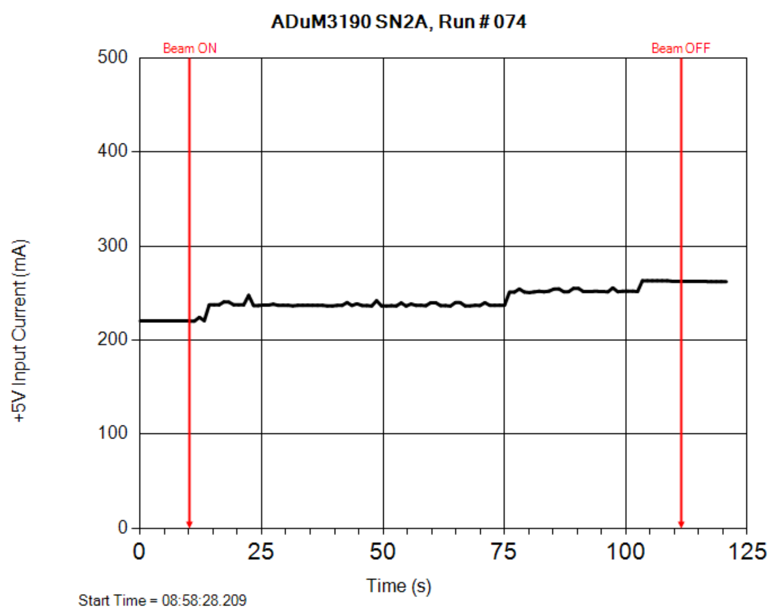

Figure E-2. ADuM3190 SN2A, Run #74, +5V Input Current (mA).

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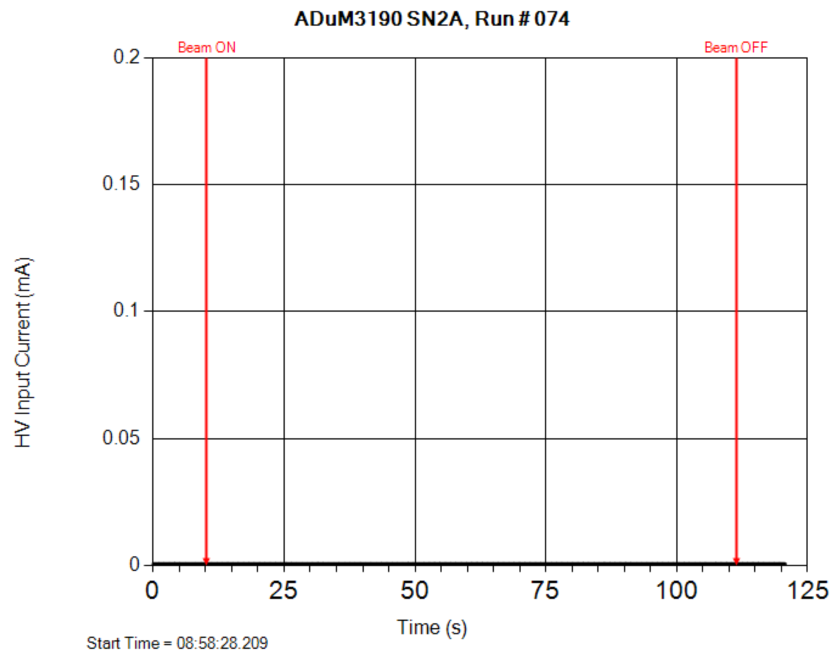

Figure E-3. ADuM3190 SN2A, Run #74, HV Input Current (mA).

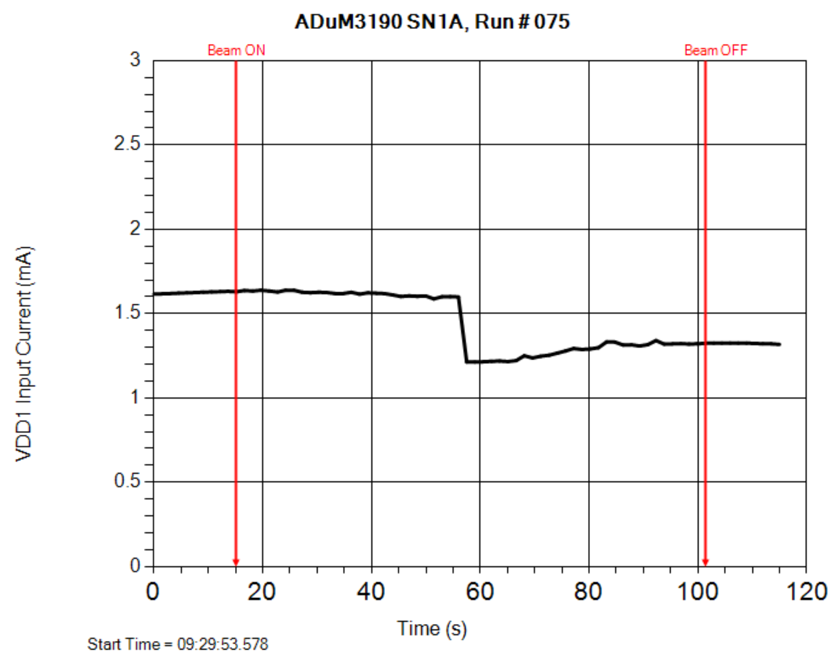

Figure E-4. ADuM3190 SN1A, Run #75, DUT VDD1 Input Current (mA).

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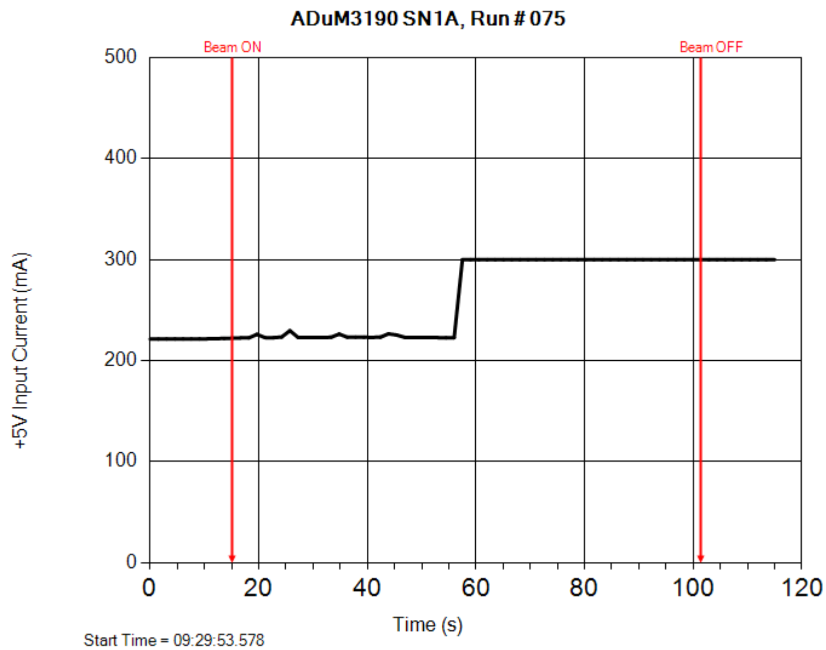

Figure E-5. ADuM3190 SN1A, Run #75, +5V Input Current (mA).

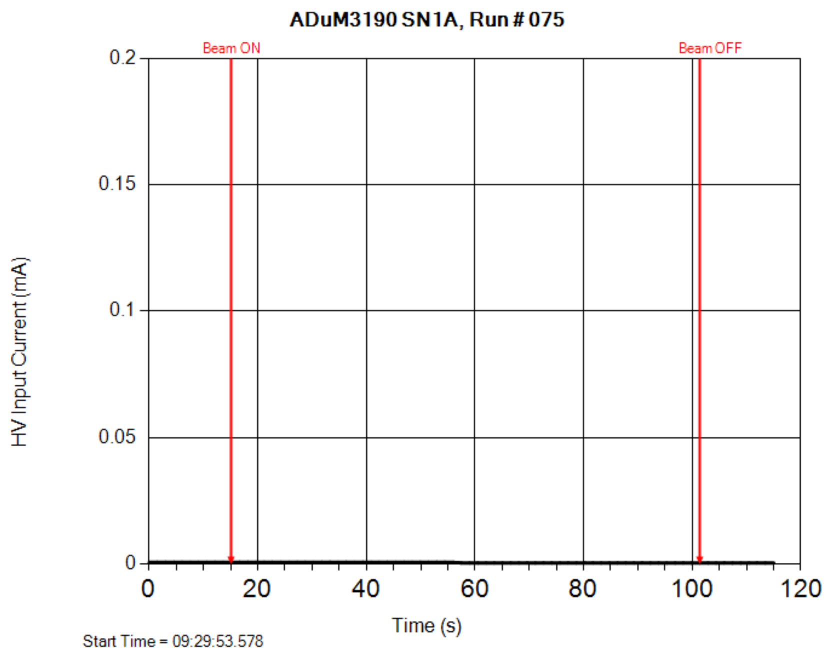

Figure E-6. ADuM3190 SN1A, Run #75, HV Input Current (mA).

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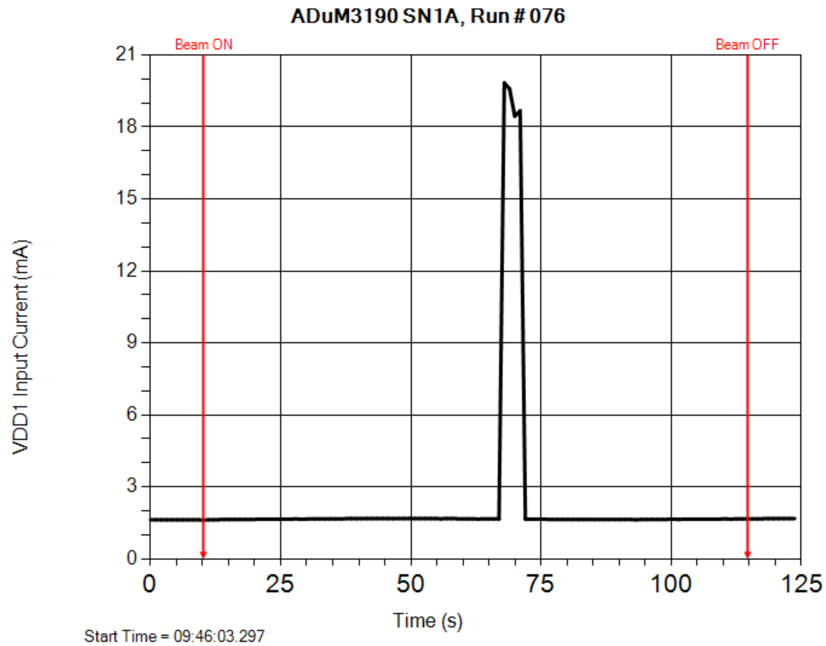

Figure E-7. ADuM3190 SN1A, Run #76, DUT VDD1 Input Current (mA).

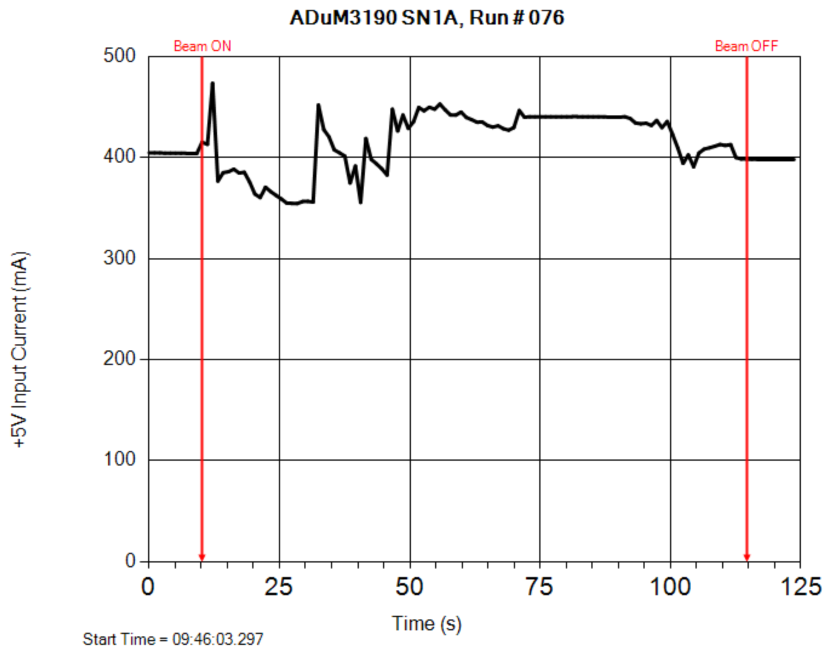

Figure E-8. ADuM3190 SN1A, Run #76, +5V Input Current (mA).

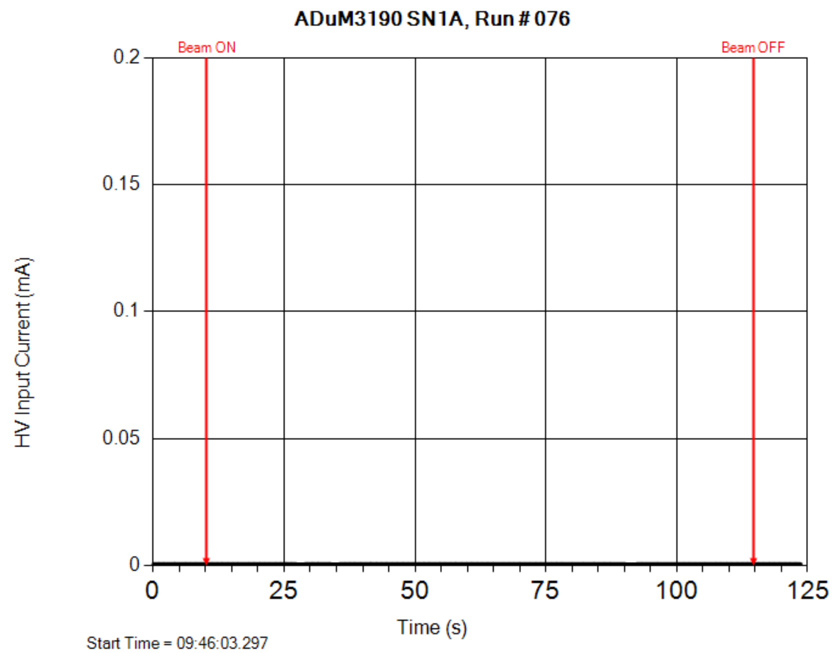

Figure E-9. ADuM3190 SN1A, Run #76, HV Input Current (mA).

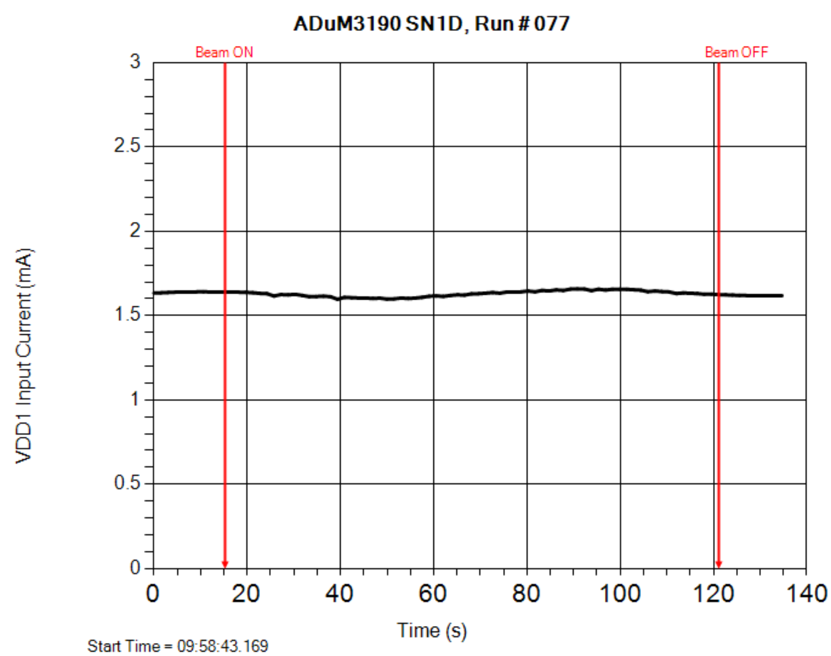

Figure E-10. ADuM3190 SN1D, Run #77, DUT VDD1 Input Current (mA).

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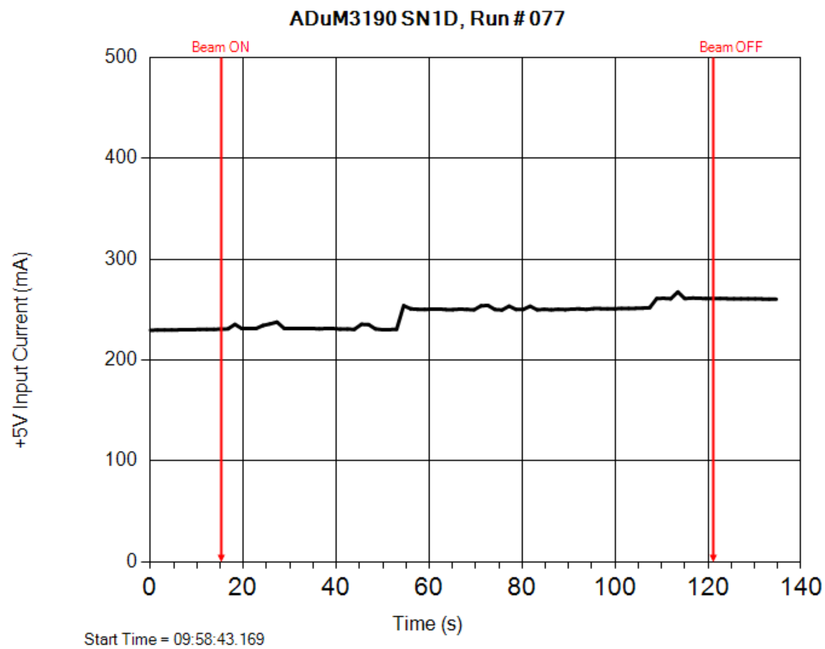

Figure E-11. ADuM3190 SN1D, Run #77, +5V Input Current (mA).

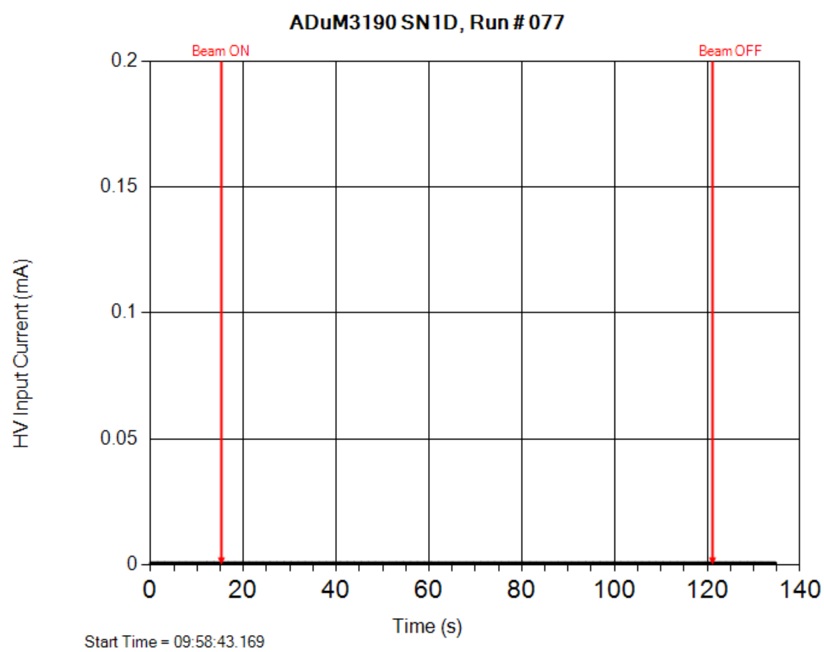

Figure E-12. ADuM3190 SN1D, Run #77, HV Input Current (mA).

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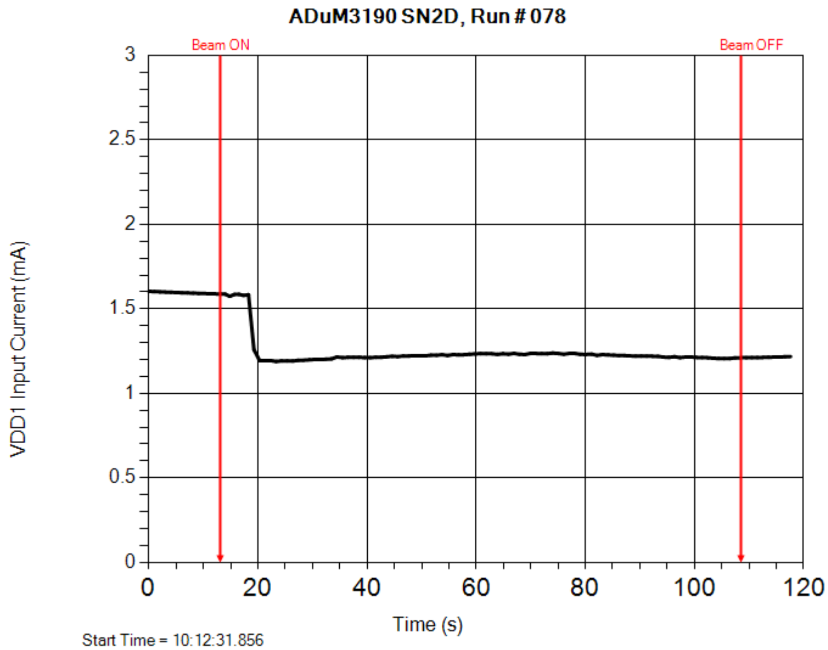

Figure E-13. ADuM3190 SN2D, Run #78, DUT VDD1 Input Current (mA).

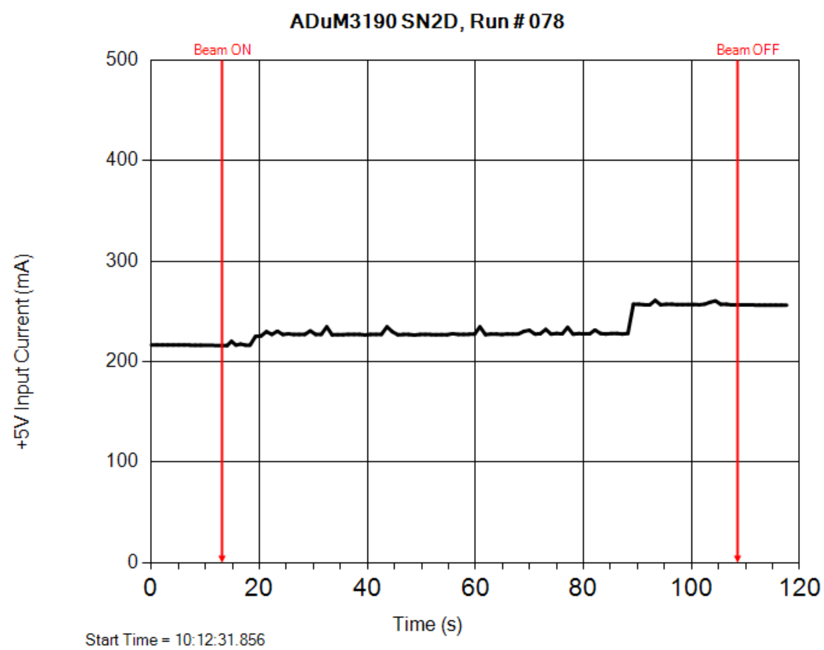

Figure E-14. ADuM3190 SN2D, Run #78, +5V Input Current (mA).

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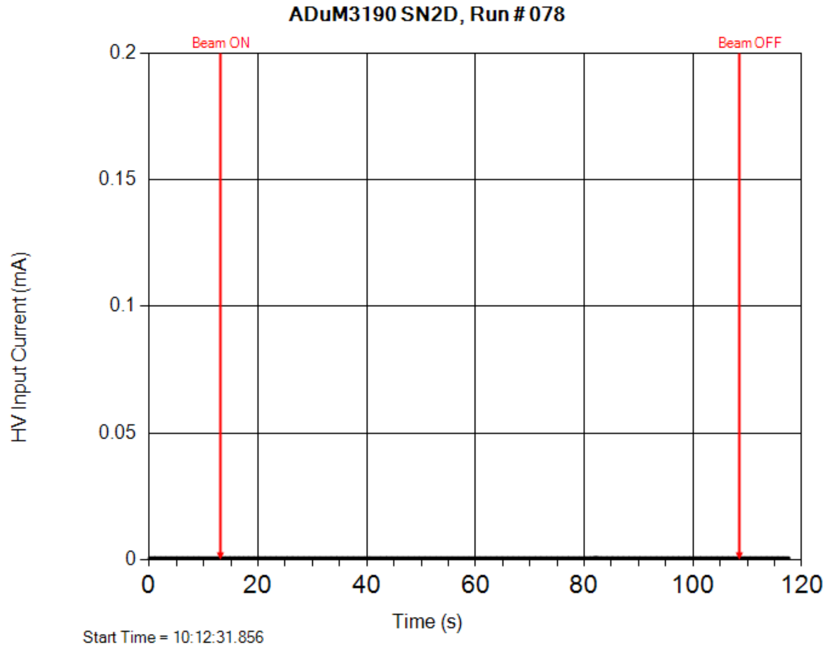

Figure E-15. ADuM3190 SN2D, Run #78, HV Input Current (mA).

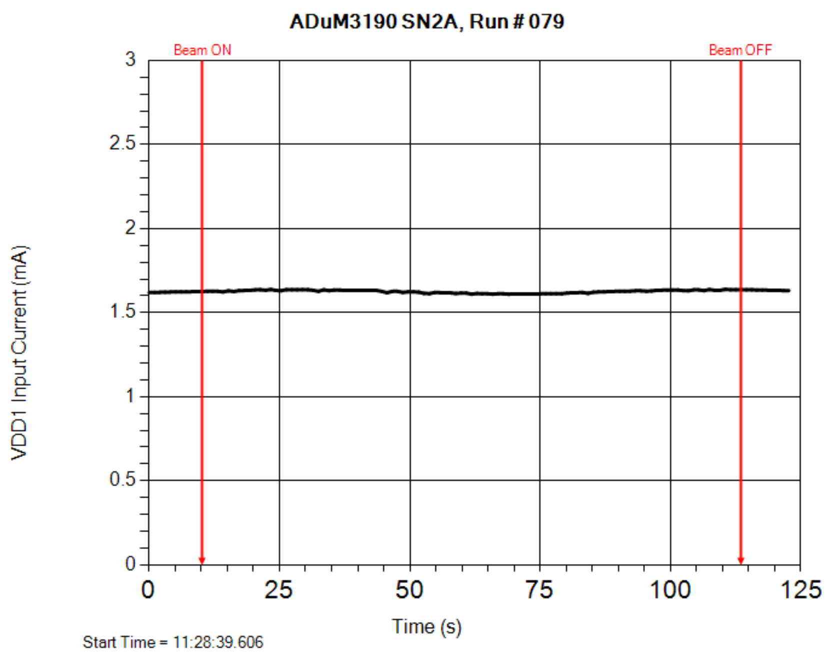

Figure E-16. ADuM3190 SN2A, Run #79, DUT VDD1 Input Current (mA).

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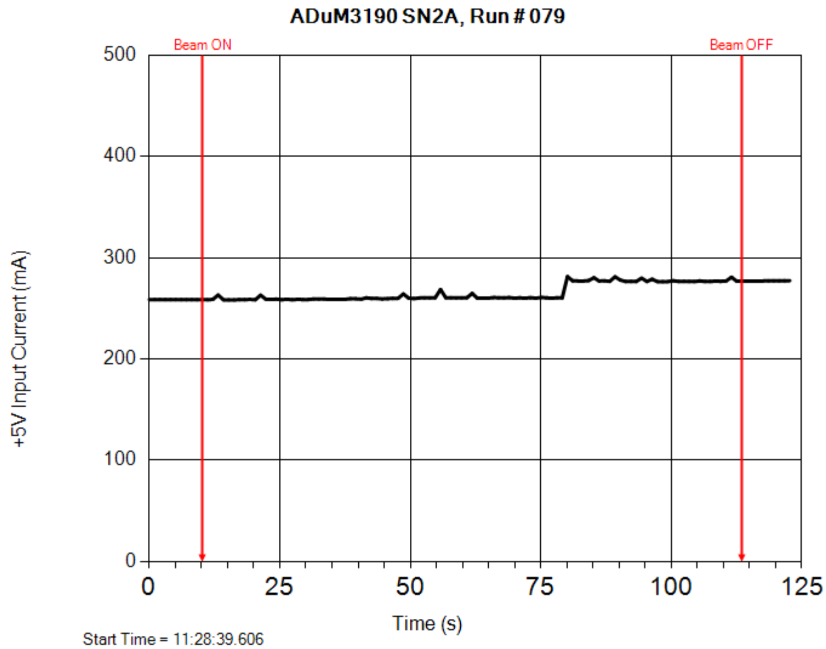

Figure E-17. ADuM3190 SN2A, Run #79, +5V Input Current (mA).

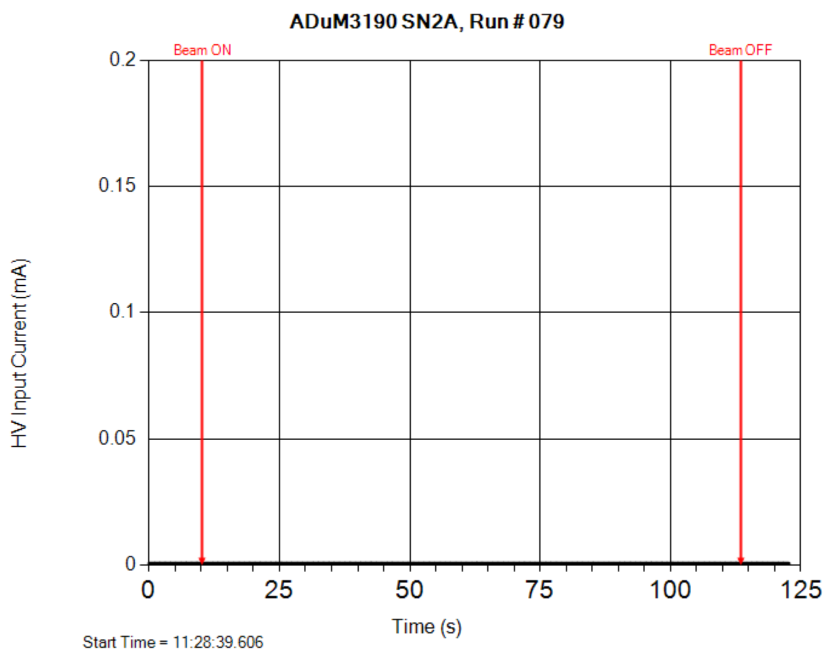

Figure E-18. ADuM3190 SN2A, Run #79, HV Input Current (mA).

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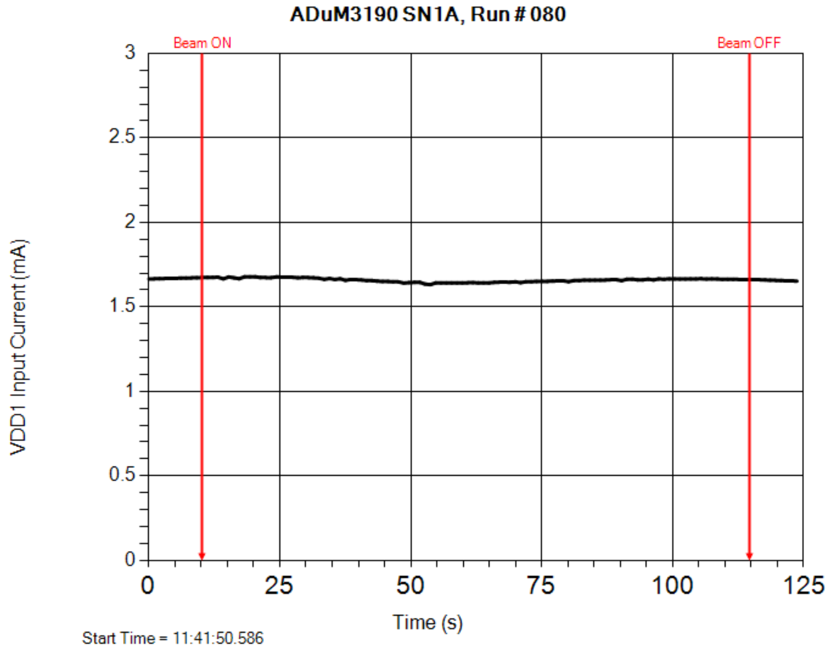

Figure E-19. ADuM3190 SN1A, Run #80, DUT VDD1 Input Current (mA).

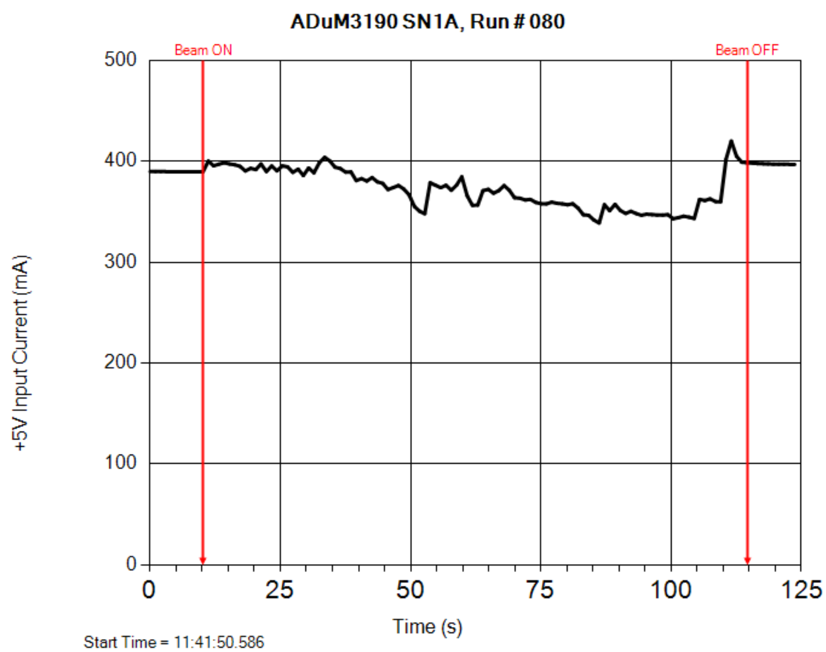

Figure E-20. ADuM3190 SN1A, Run #80, +5V Input Current (mA).

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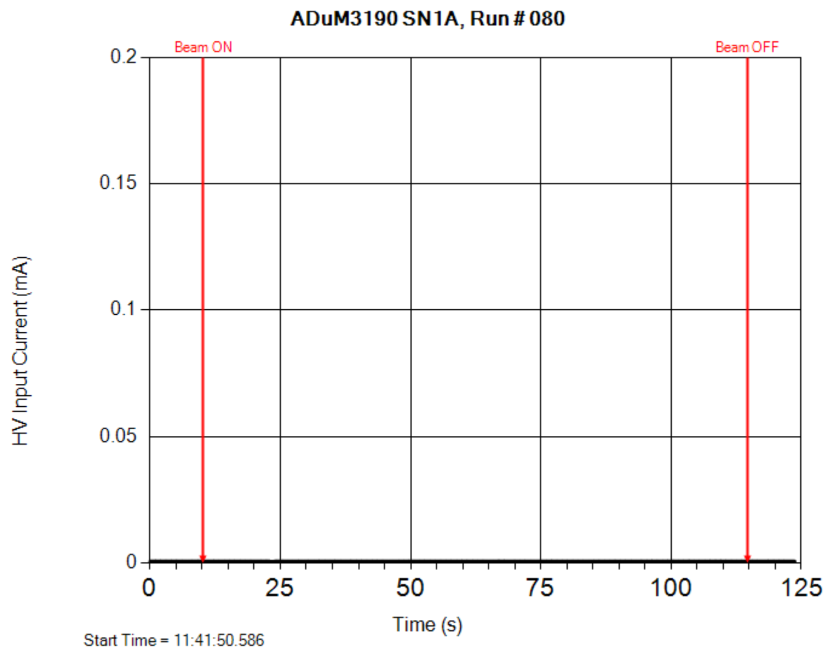

Figure E-21. ADuM3190 SN1A, Run #80, HV Input Current (mA).

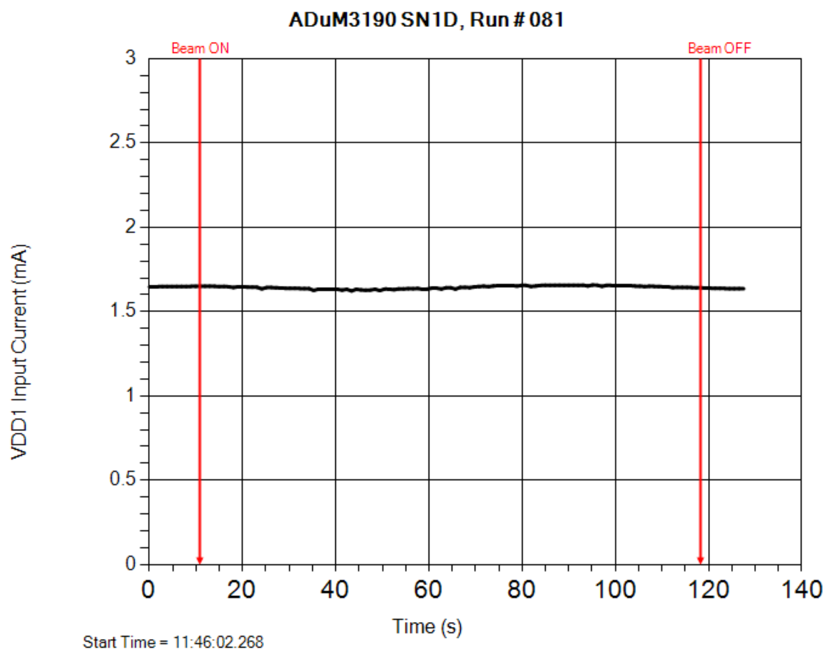

Figure E-22. ADuM3190 SN1D, Run #81, DUT VDD1 Input Current (mA).

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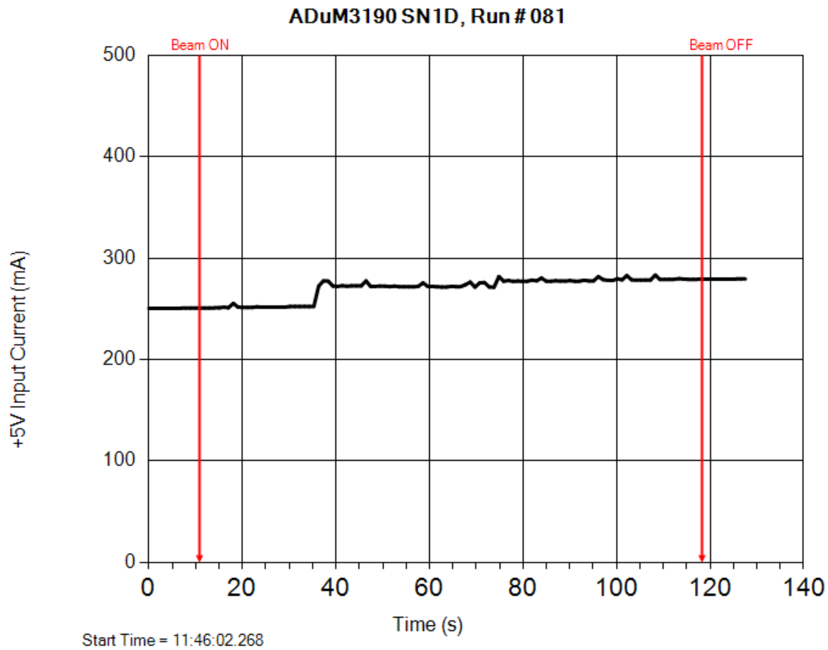

Figure E-23. ADuM3190 SN1D, Run #81, +5V Input Current (mA).

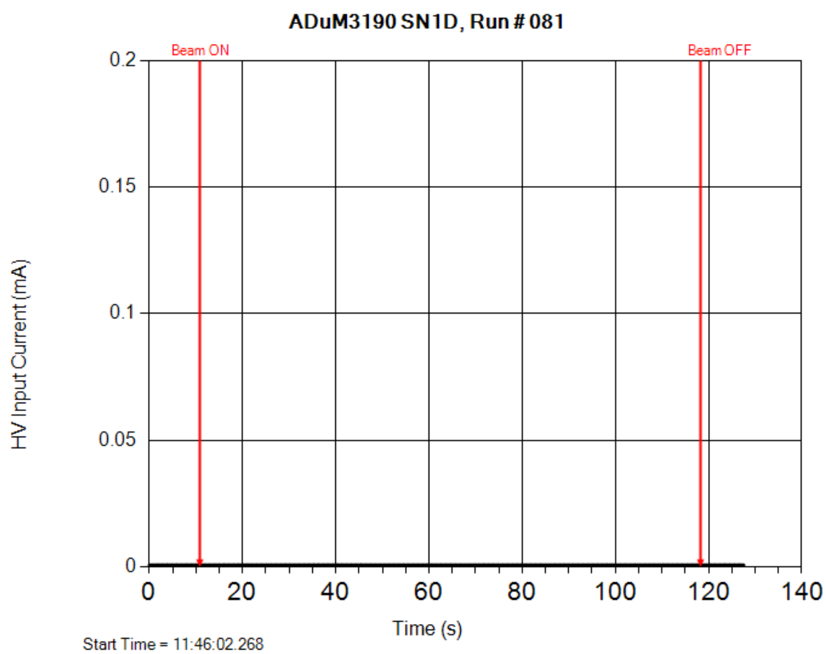

Figure E-24. ADuM3190 SN1D, Run #81, HV Input Current (mA).

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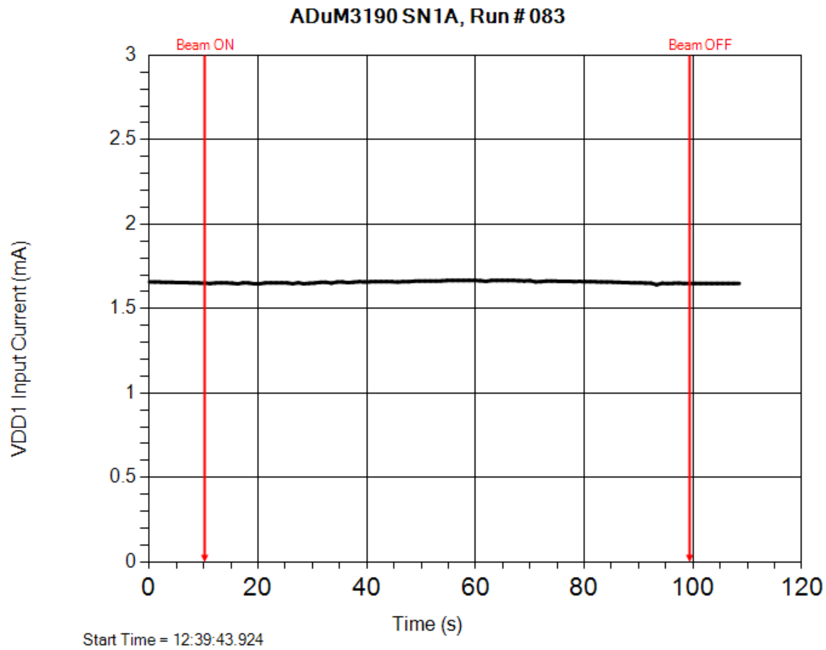

Figure E-25. ADuM3190 SN1A, Run #83, DUT VDD1 Input Current (mA).

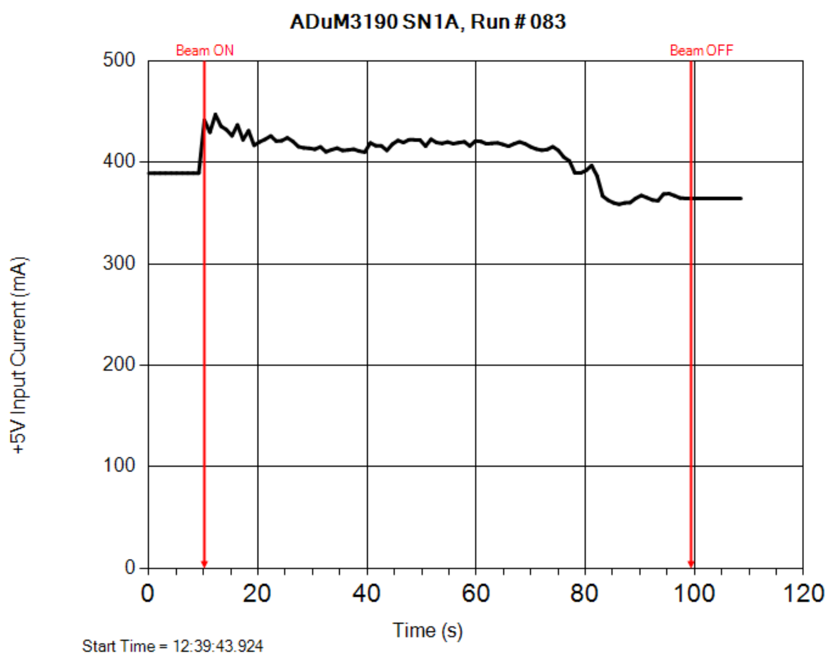

Figure E-26. ADuM3190 SN1A, Run #83, +5V Input Current (mA).

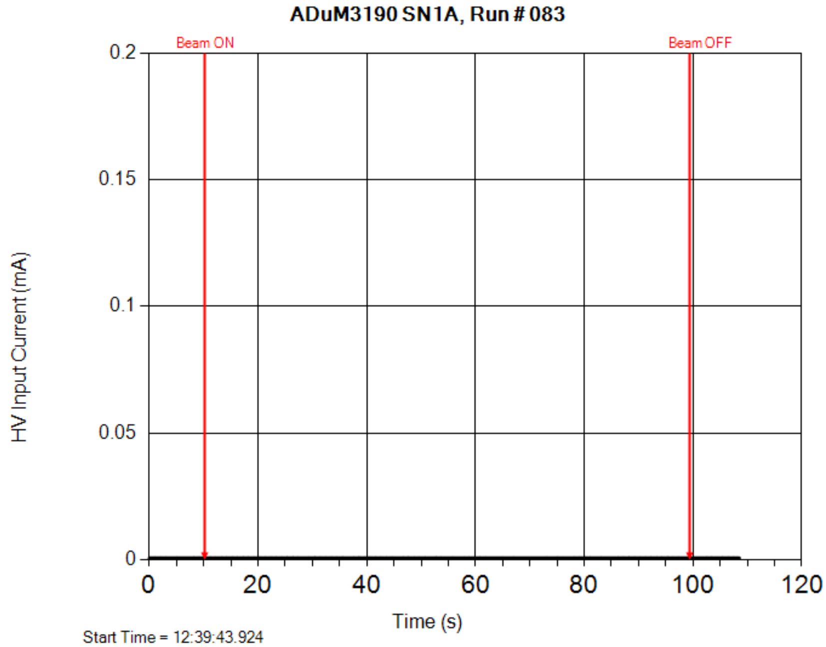

Figure E-27. ADuM3190 SN1A, Run #83, HV Input Current (mA).

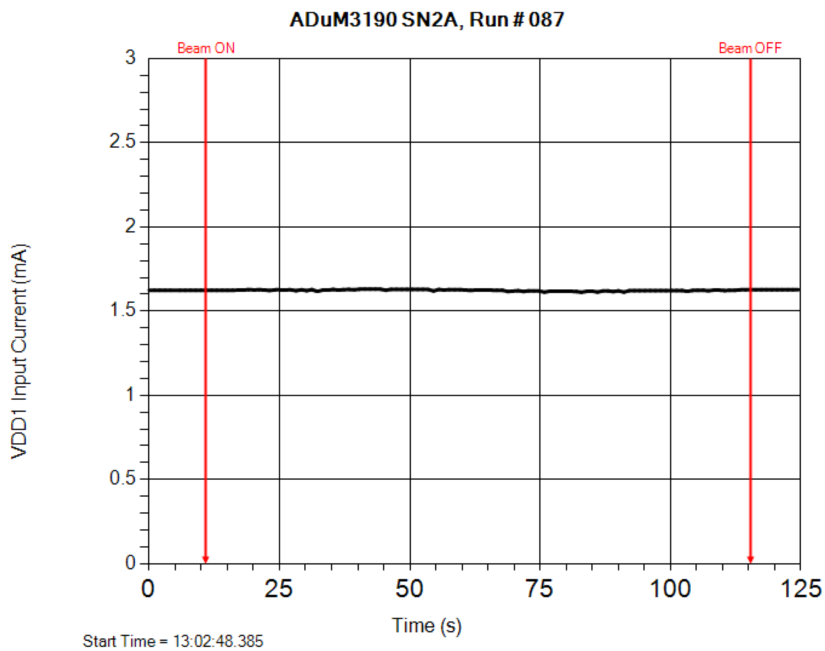

Figure E-28. ADuM3190 SN2A, Run #87, DUT VDD1 Input Current (mA).

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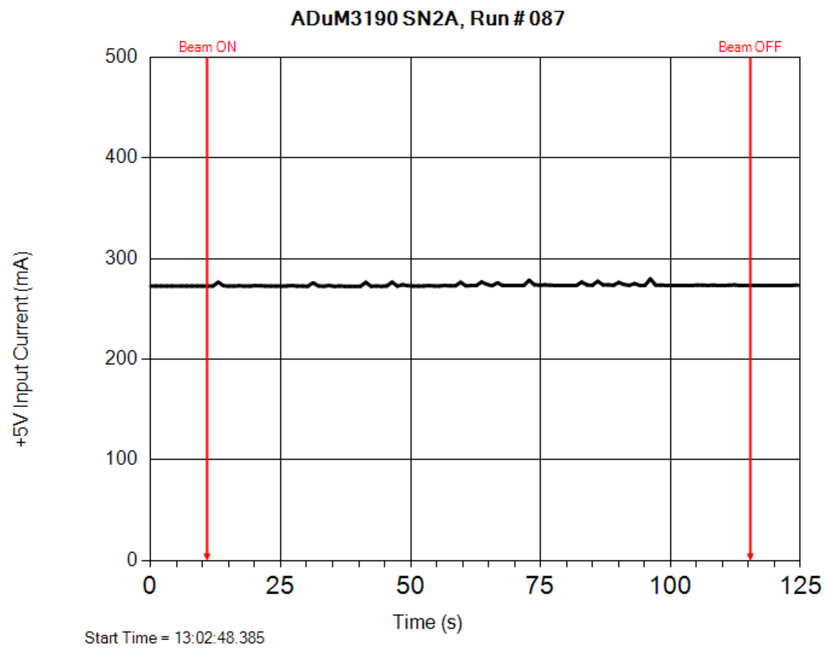

Figure E-29. ADuM3190 SN2A, Run #87, +5V Input Current (mA).

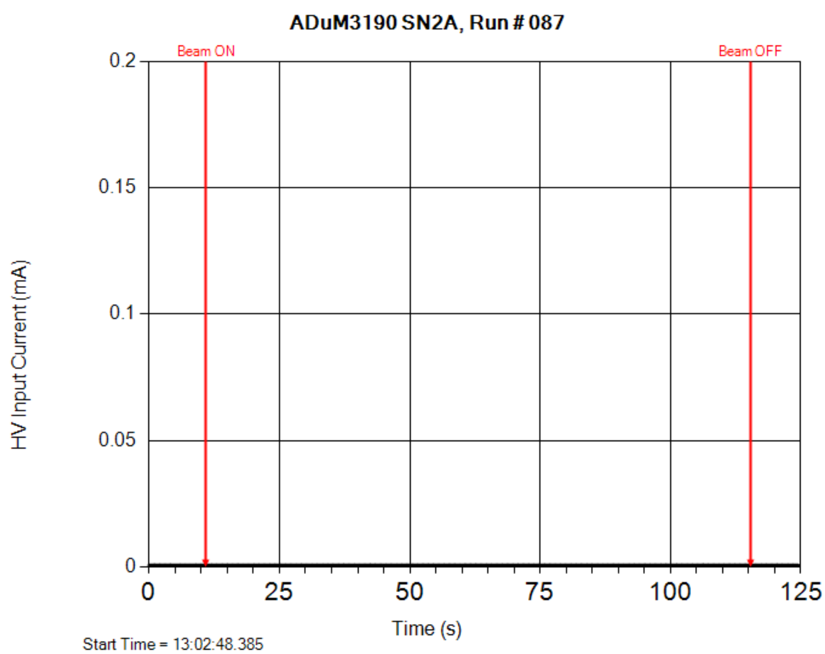

Figure E-30. ADuM3190 SN2A, Run #87, HV Input Current (mA).

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Appendix F: SET Current and Voltage Plots

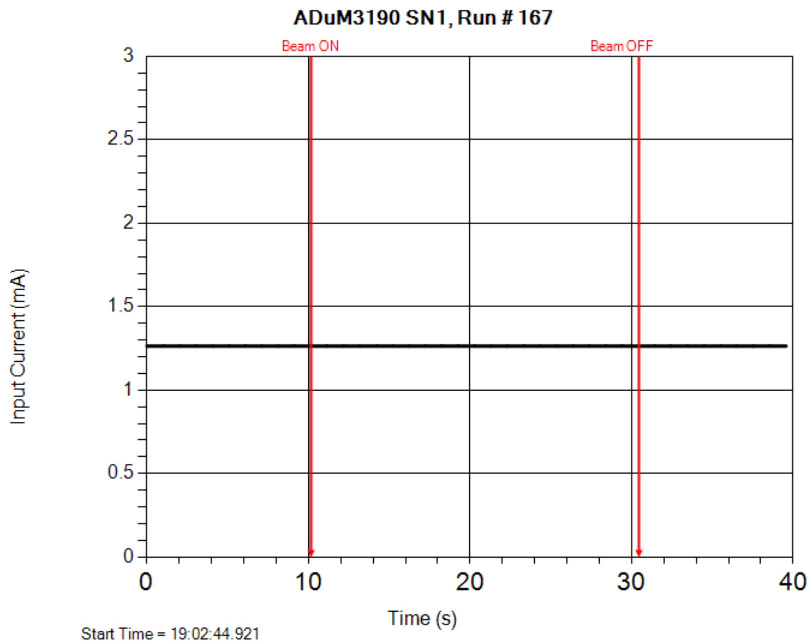

Figure F-1. ADuM3190 SN1, Run #167, DUT Input Current (mA).

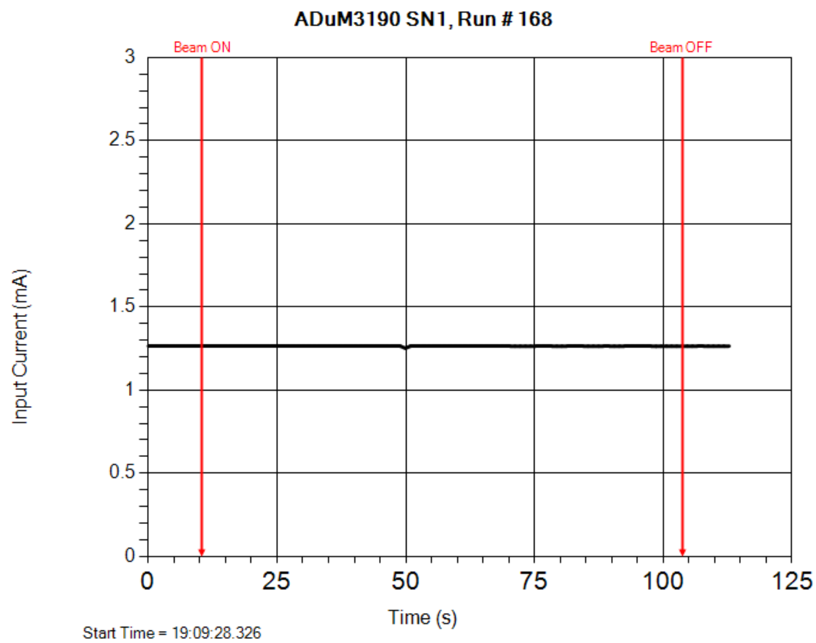

Figure F-2. ADuM3190 SN1, Run #168, DUT Input Current (mA).

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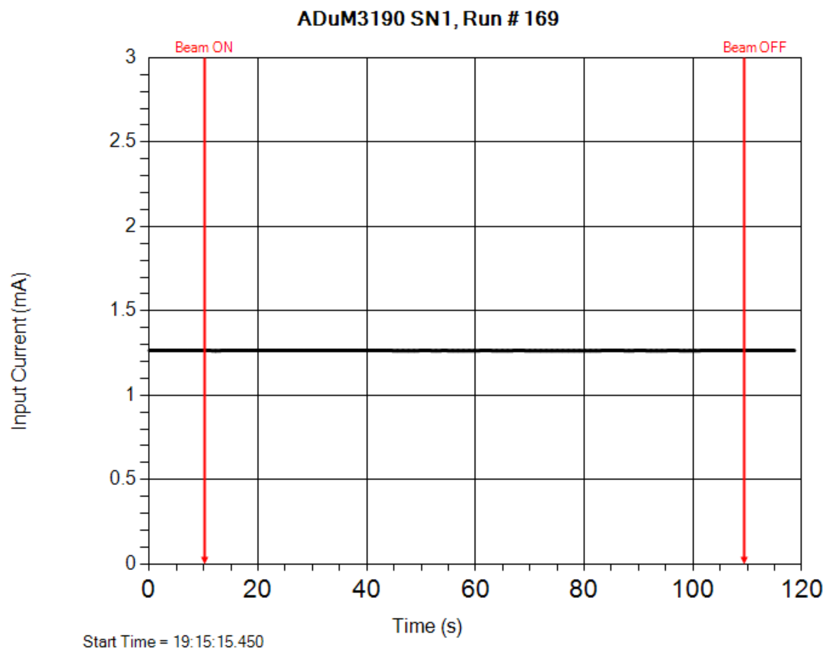

Figure F-3. ADuM3190 SN1, Run #169, DUT Input Current (mA).

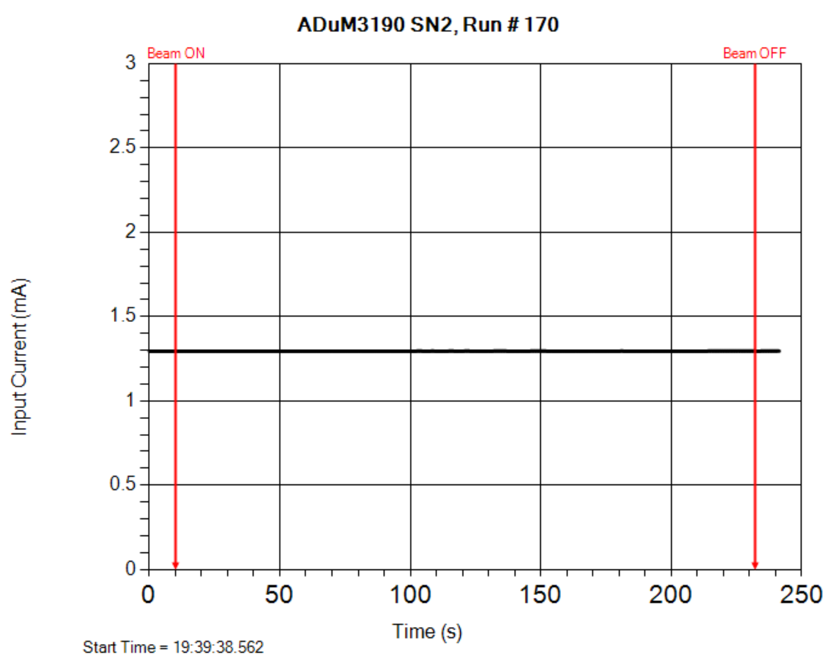

Figure F-4. ADuM3190 SN2, Run #170, DUT Input Current (mA).

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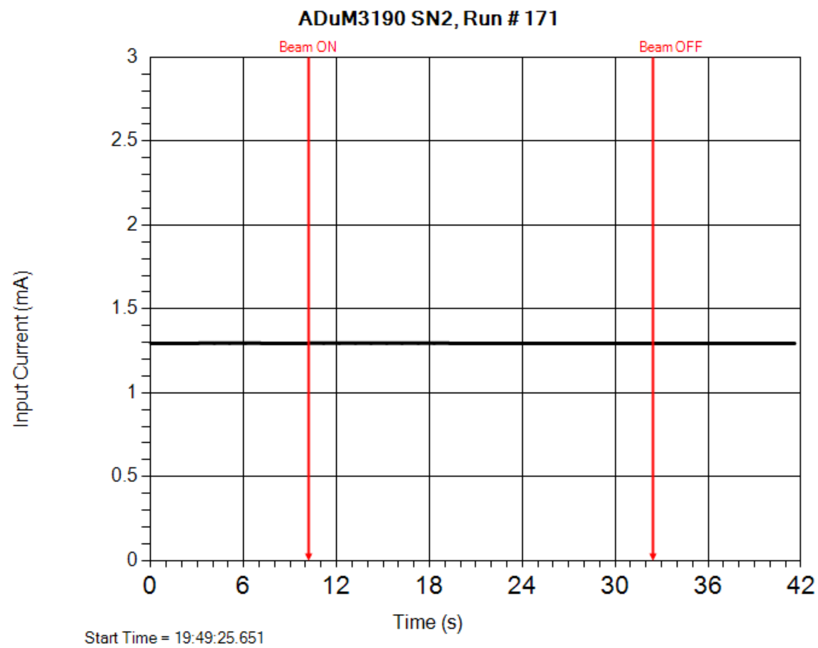

Figure F-5. ADuM3190 SN2, Run #171, DUT Input Current (mA).

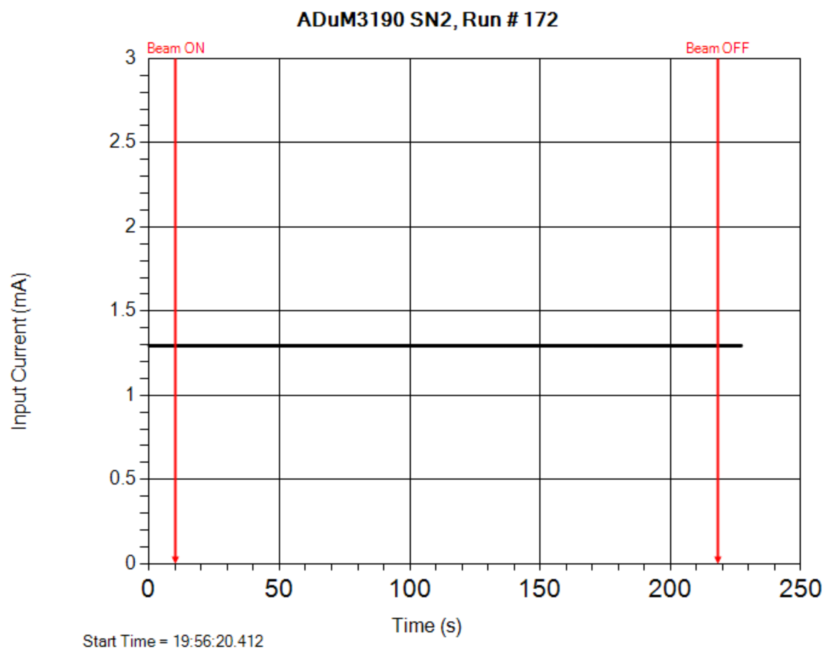

Figure F-6. ADuM3190 SN2, Run #172, DUT Input Current (mA).

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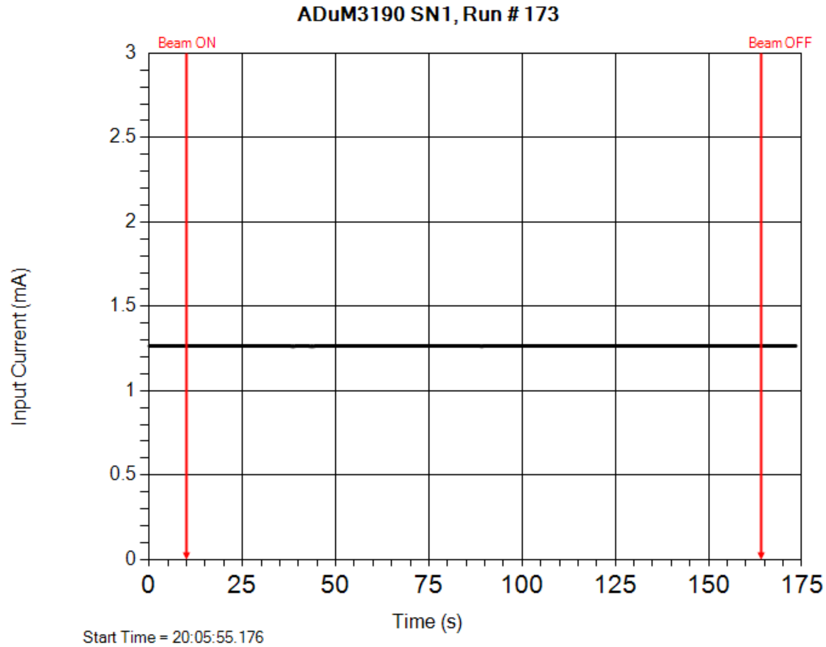

Figure F-7. ADuM3190 SN1, Run #173, DUT Input Current (mA).

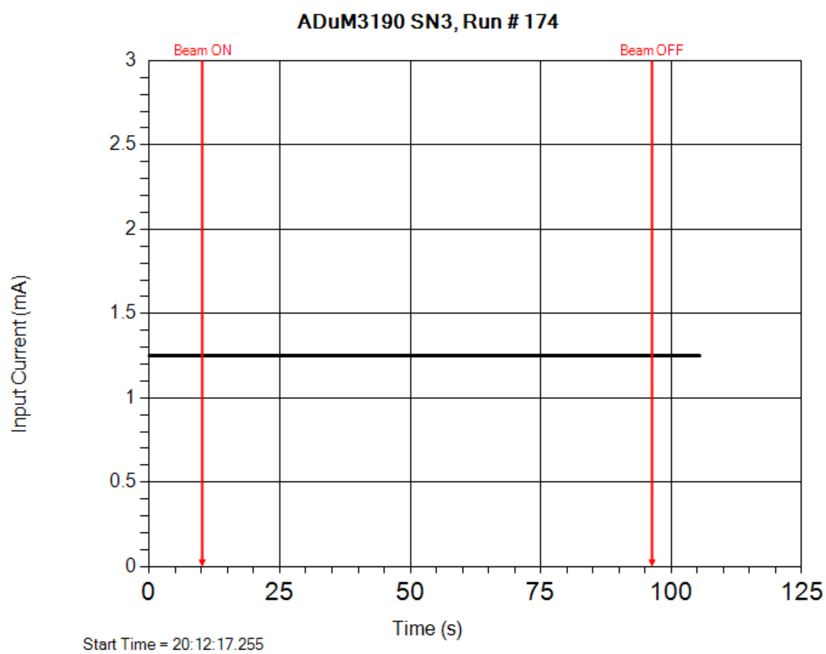

Figure F-8. ADuM3190 SN3, Run #174, DUT Input Current (mA).

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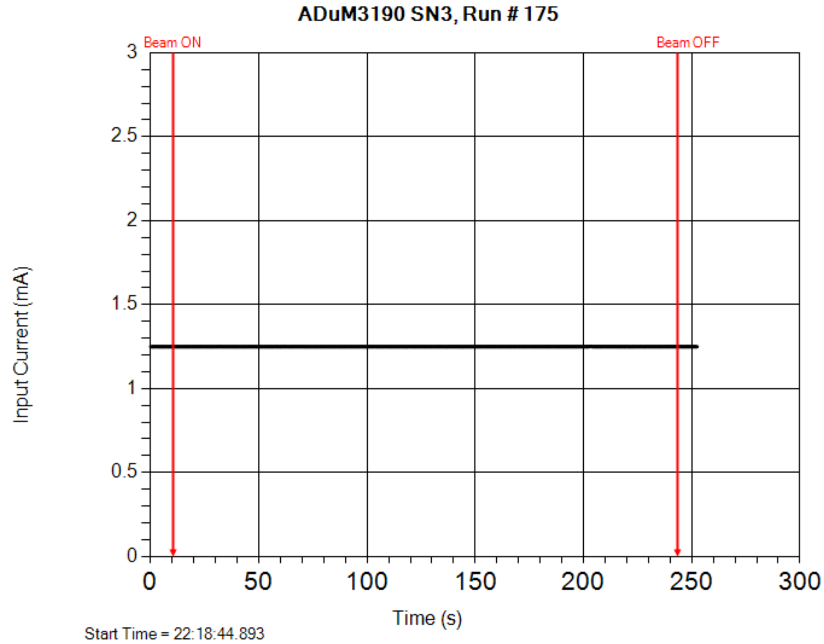

Figure F-9. ADuM3190 SN3, Run #175, DUT Input Current (mA).

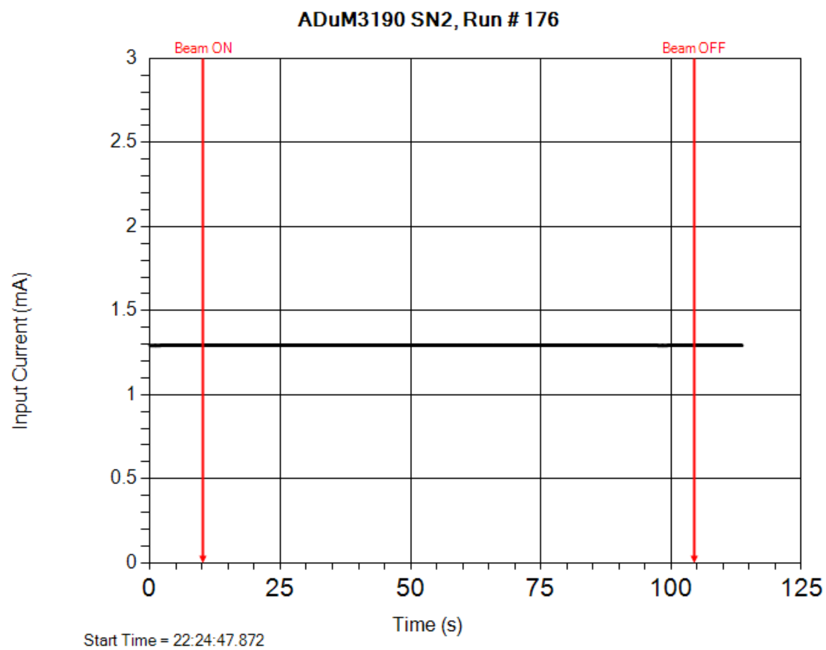

Figure F-10. ADuM3190 SN2, Run #176, DUT Input Current (mA).

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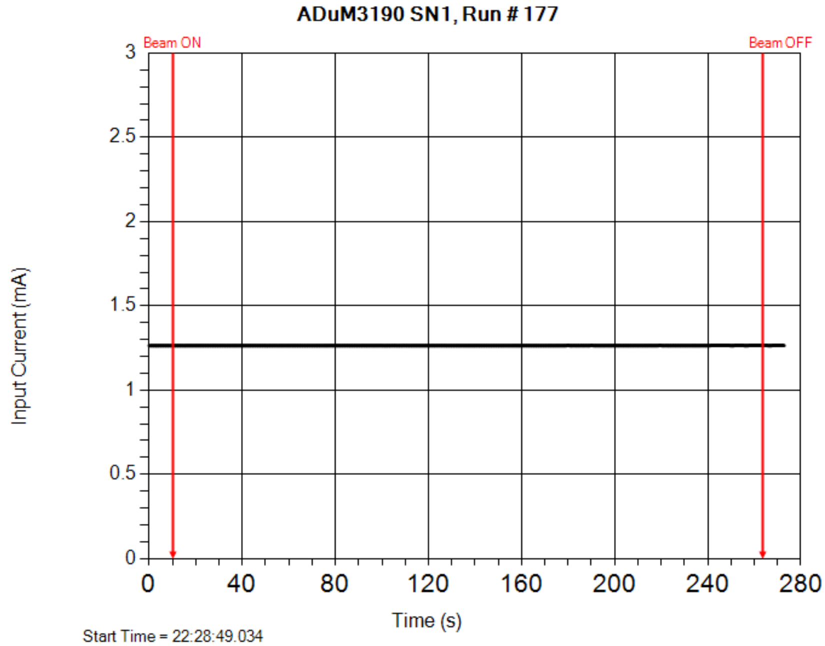

Figure F-11. ADuM3190 SN1, Run #177, DUT Input Current (mA).

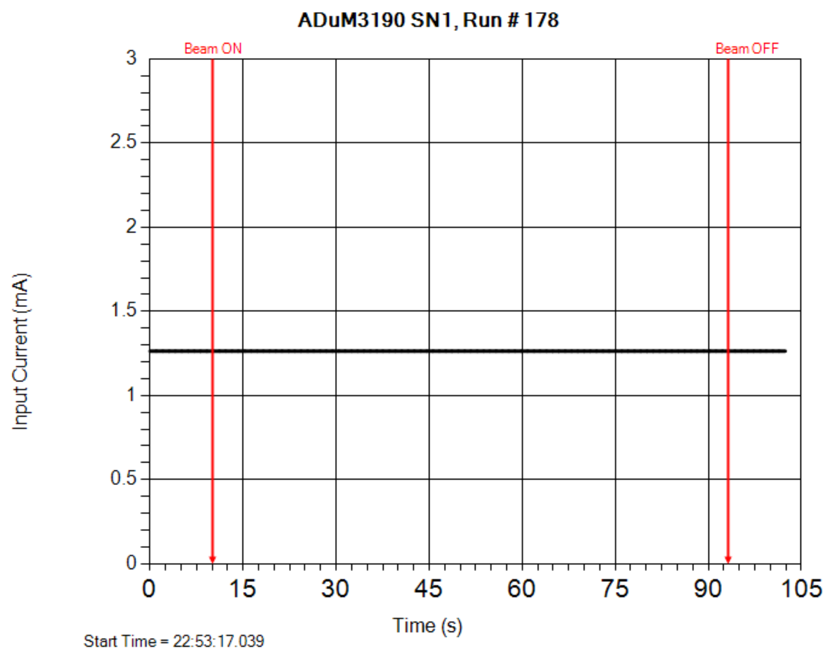

Figure F-12. ADuM3190 SN1, Run #178, DUT Input Current (mA).

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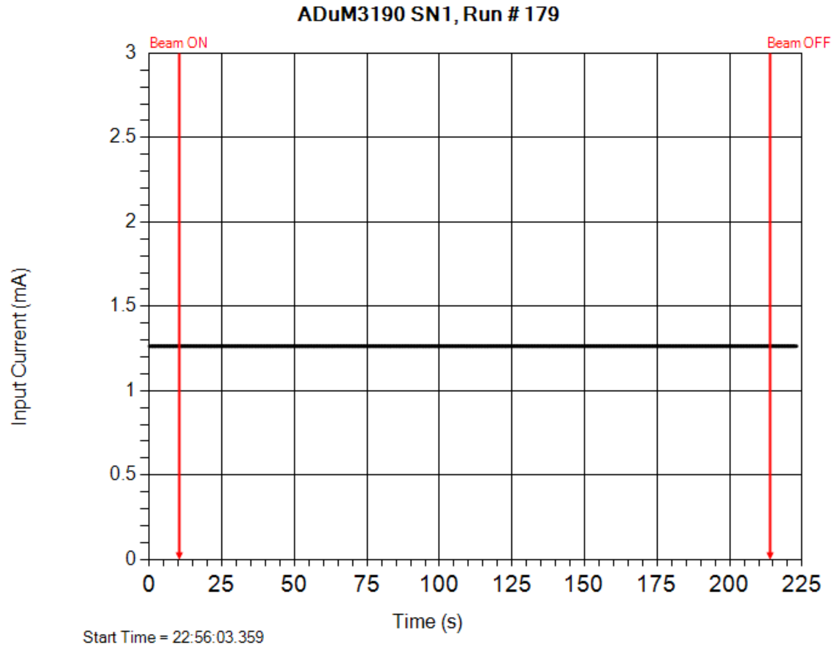

Figure F-13. ADuM3190 SN1, Run #179, DUT Input Current (mA).

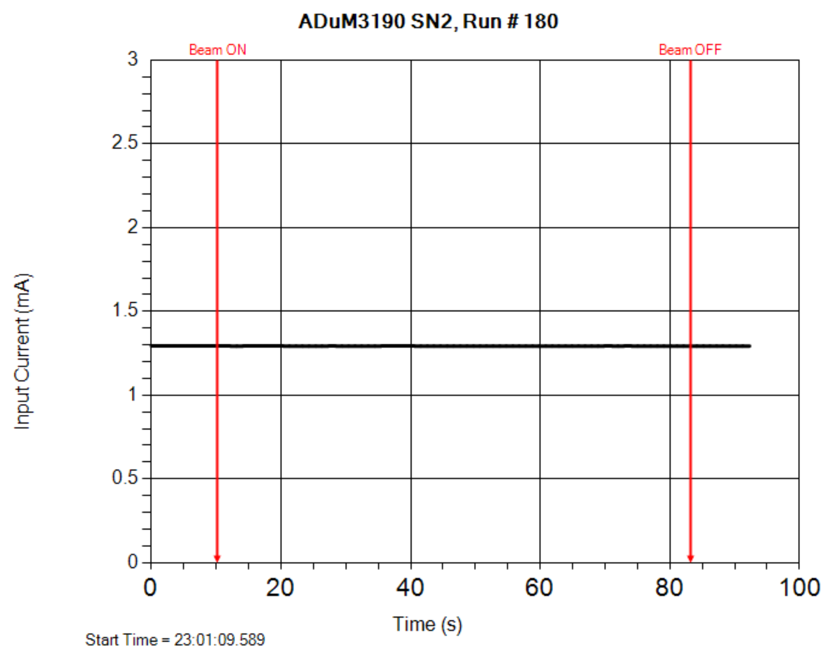

Figure F-14. ADuM3190 SN2, Run #180, DUT Input Current (mA).

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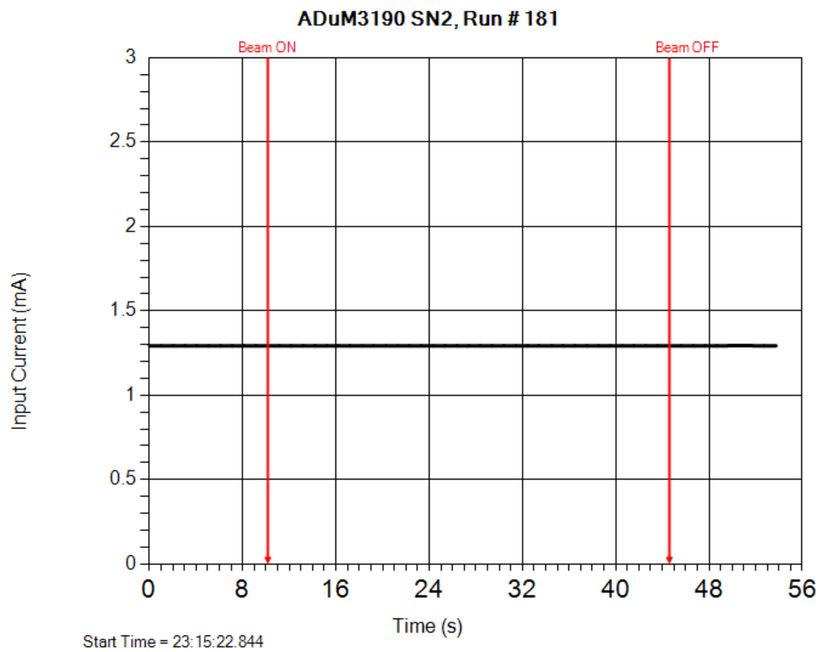

Figure F-15. ADuM3190 SN2, Run #181, DUT Input Current (mA).

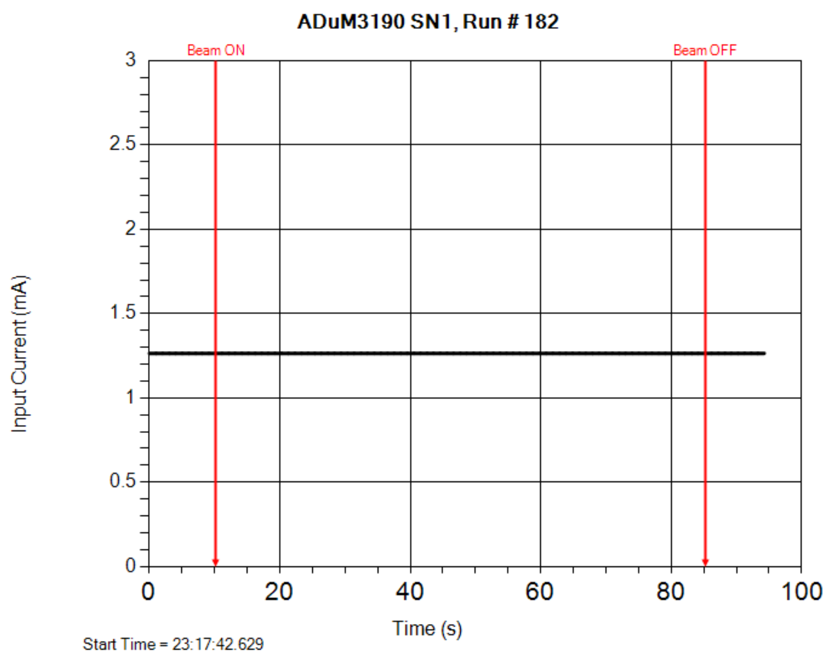

Figure F-16. ADuM3190 SN1, Run #182, DUT Input Current (mA).

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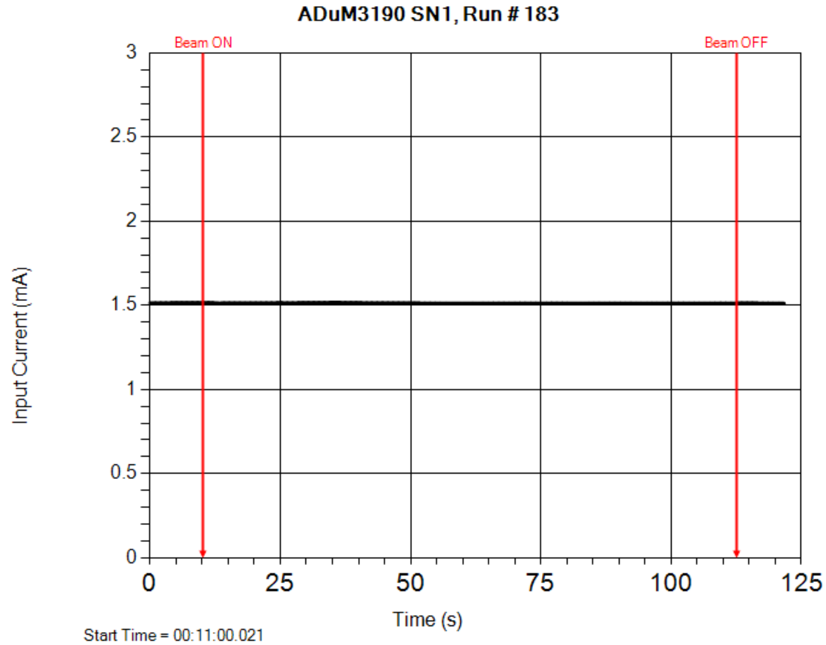

Figure F-17. ADuM3190 SN1, Run #183, DUT Input Current (mA).

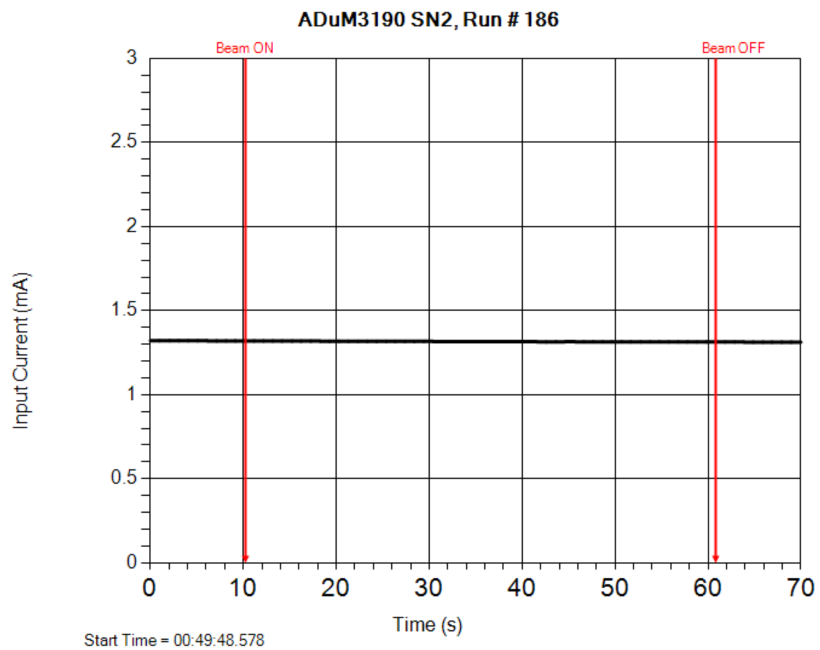

Figure F-18. ADuM3190 SN2, Run #186, DUT Input Current (mA).

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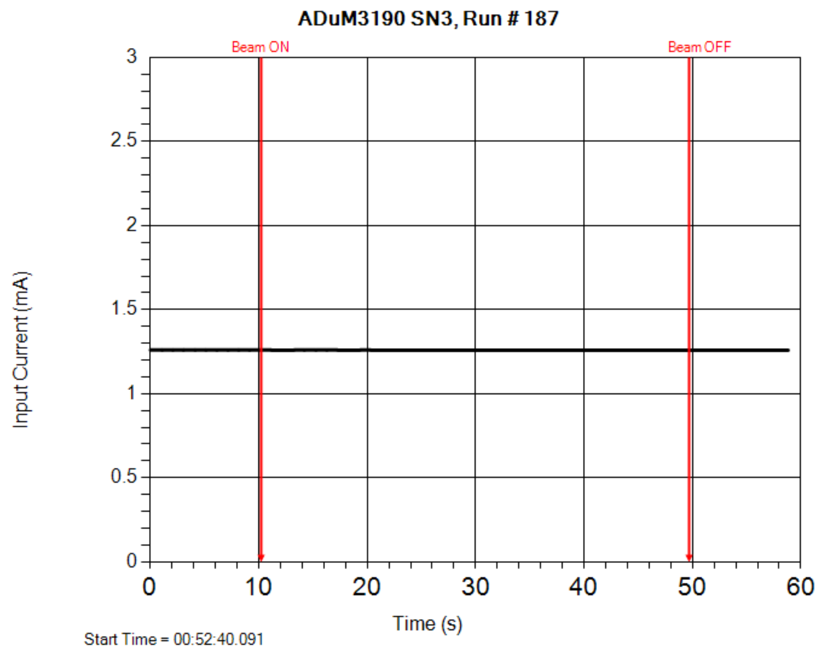

Figure F-19. ADuM3190 SN3, Run #187, DUT Input Current (mA).