Introduction

The intense proton and heavy-ion environment encountered in space applications can cause a variety of Single Event Effects (SEE) in electronic circuitry, including Single Event Upset (SEU), Single Event Transient (SET), Single Event Functional Interrupt (SEFI), Single Event Latch-Up (SEL), Single Event Gate Rupture (SEGR), and Single Event Burnout (SEB). SEE can lead to system-level performance issues including disruption, degradation, and destruction. For predictable and reliable space system operation, individual electronic components should be characterized to determine their SEE response. This report discusses the results of SEE testing performed on the ISL73141SEH product. The ISL73141SEH is offered with radiation assurance screening to 75krad(Si) at 10mrad(Si)/s. This report applies to both the 3.3V (ISL73141SEHMFN) and the 5V (ISL73141SEHMF7) versions of the ISL73141SEH.

SEE Summary

The ISL73141SEH proved to be free of Destructive Single Event Effects (DSEE) including SEL with AIN set to $5.1V_{DC}$ at supply voltages up to AV_{CC} = 6.3V, DV_{CC} = 4.6V, and V_{REF} = 5.1V with a die temperature of 125°C when irradiated with normal incidence gold for a Linear Energy Transfer (LET) of 86MeV·cm^2/mg.

The ADC exhibited SET that primarily lasted for a single sample and recovered to normal operation thereafter without any user intervention required indicating the device had no SEFI. The number and magnitude of SET decreased as the LET decreased. No observed SET lasted for longer than three samples. Of all the observed SET during testing, 91.47% were single sample events and 96.98% were less than 100 codes in magnitude. Out of the total number of samples observed during testing, 0.0015% of samples exhibited a SET.

SEE testing was performed on two different test dates with a cumulative dose effect being observed on the first test date. This cumulative dose effect resulted in a reduction in the number of SETs as the effective total dose increased during testing. On the second test date, the total fluence was reduced from $1x10^7$ion/cm^2 down to $2x10^6$ion/cm^2 and more devices under test (DUTs) reduced the cumulative dose.

Part Description

The ISL73141SEH is a radiation tolerant high precision 14-bit SAR ADC (analog-to-digital converter) operating up to 1Msps from a 5V supply and up to 750ksps with a 3.3V supply.

The product features 1Msps throughput with no data latency and features excellent linearity and dynamic accuracy. The ISL73141SEH offers a high-speed SPI-compatible serial interface that supports logic ranging from 2.2V to 3.6V using a separate digital I/O supply pin.

The ISL73141SEH offers a separate power-down pin, which reduces power dissipation to <50µW. The analog input signal range is determined by an external reference with a supported input range of 1.5V to A_{VCC} or 4.2V, whichever is lower.

The ISL73141SEH operates across the military temperature range from -55°C to +125°C and is available in a 14 lead hermetically sealed Ceramic Dual Flat-Pack (CDFP) package.

The SEE testing of the ISL73141SEH was completed on two silicon versions with differences only in metal layers. During the first test session, Revision A silicon was used. Revision B silicon (released production silicon version) was used during the second (final) test session. Wafer information for the first test session was not logged, but for the final test session, three lots from a single wafer were used, V6C498, V6C565, and V6C566.

Because the production silicon version is Revision B, the results from that version are focused on. However, the results from Revision A can be cited as well because the silicon design is similar between the two revisions and the results from the versions provide some information on manufacturing variability.

The samples were packaged without lids to allow irradiation, and only room temperature testing of the parts was done. No burn-in stressing was done on the parts.

Contents

1. SEE Testing

1.1 Objective

The testing was intended to find the limits of the supply voltages set by the onset of Destructive Single Event Effects (DSEE) at a LET of 86MeV·cm^2/mg (normal incidence gold). Additional testing was intended to identify and quantify SETs and SEFIs occurring in the output sample codes of the ISL73141SEH. The SET studies included irradiation with normal incidence gold (86MeV·cm^2/mg), silver (43MeV·cm^2/mg), copper (20MeV·cm^2/mg), argon (8.5MeV·cm^2/mg), neon (2.7MeV·cm^2/mg), nitrogen (1.3MeV·cm^2/mg), and helium (0.11MeV·cm^2/mg).

1.2 Facility

SEE testing was done at the Texas A&M University (TAMU) Radiation Effects Facility of the Cyclotron Institute in College Station Texas. This facility is coupled to a K500 superconducting cyclotron that can supply a wide range of ion species and flux. The testing referred to in this report was done on September 28-29, 2019 and April 6-8, 2020.

1.3 Setup

The ISL73141SEH was SEE evaluated using a general-purpose engineering evaluation board that allowed various application configurations to be used. The specific configurations changed with the type of testing. For destructive SEE testing (collectively called DSEE herein), the individual supply voltages and analog input were driven directly from an external power supply with currents monitor using an ammeter. For the SET testing, external power supplies supplied ±10V to the evaluation board and the ISL73141SEH supply voltages were generated by on-board LDOs while an on-board amplifier circuit connected to the analog input set the ADC input to midscale. The on-board LDOs kept noise to a minimum and allow for fine resolution of SET detection.

For the DSEE testing, the ADC input clock (CSB) was set to 1MHz sampling rate, AV_{CC} varied up to 6.5V, and DV_{CC} set to 4.6V. The maximum sampling rate and the maximum voltages were used for AV_{CC} and DV_{CC} to achieve the worst-case conditions. The monitored parameters for the ADC are listed in Table 1.

Table 1. Monitored Parameters and Failure Criteria for the ISL73141SEH DSEE Testing

Parameter Monitored	Failure Criteria
AV_{CC} Supply Current	±10%
DV_{CC} Supply Current	±10%
V_{REF} Supply Current	±10%
AIN Input Current	±10%

For DSEE testing, the DV_{CC} (4.6V), V_{REF} (5.1V), and AIN (5.1V) input voltages were held constant during both test dates. During the testing in September 2019, the AV_{CC} voltage was started at 5.8V and increased in 0.1V steps until DSEE was observed or 6.5V was reached. During the testing in April 2020, the AV_{CC} voltage was started at 6.2V and increased in 0.1V steps until DSEE was observed or 6.5V was reached. During both test dates, the sample rate was set to 1000ksps.

For SET testing, the ISL73141SEH was tested under three conditions as given in Table 4. The order of testing under these three conditions was reversed from one DUT and/or LET to the next, i.e. 1-2-3 followed by 3-2-1 followed by 1-2-3 and so on. The first condition was a low sample rate and low AV_{CC} supply, the second condition was a low sample rate and high AV_{CC} supply, and the third condition was a high sample rate and high AV_{CC} supply. For both test dates, the low AV_{CC} supply was a voltage of 3.0V and the high AV_{CC} supply was a voltage of 4.5V. These voltages correspond to the minimum voltage for the 3.3V and the 5.0V variants of the ISL73141SEH. During the September 2019 testing, the low sample rate condition was 500ksps while during April 2020 testing the low sample rate condition was 750ksps. The low sample rate was adjusted after the silicon evaluation demonstrated that the device can support 750ksps for a 3.3V operation. During both test dates, the high sample rate condition was 1000ksps.

The ISL73141SEH evaluation board contains a CPLD, which takes the serial output data from the ADC and converts it to parallel. This data is input to a logic analyzer where it is observed for any SET. Figure 1 shows the SET detection threshold that is configured inside the logic analyzer. The ADC input is set to approximately midscale using an amplifier circuit present on the ISL73141SEH engineering evaluation board driving the ADC analog input. Setting the ADC analog input to a mid-scale value enables the observation of positive and negative excursions in the output codes of the ISL73141SEH. A test run without beam is performed to find the median output code on a per-part basis, and then a ±8 code threshold is applied around that value. If the output code of the ADC goes beyond this threshold it is counted as a SET. The ±8 code threshold was found by operating the ISL73141SEH and observing no output code excursion beyond the threshold with no beam at the TAMU facility.

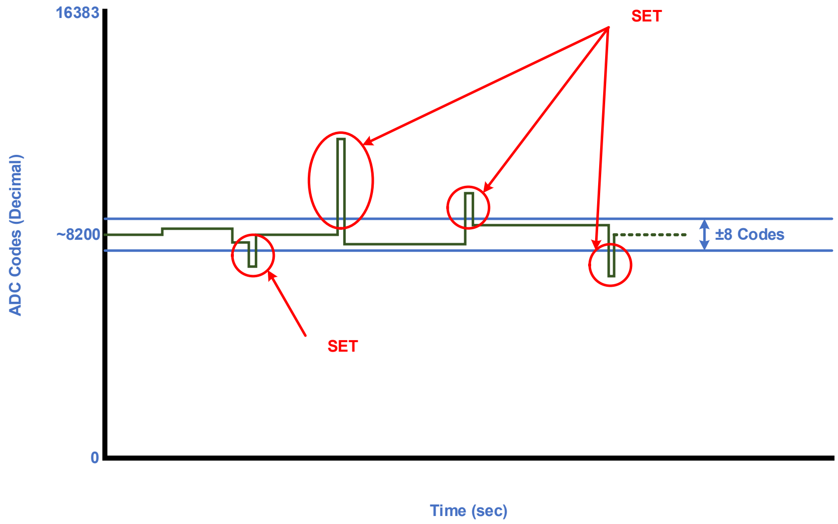

Figure 1. SET Detection Threshold

2. Results

2.1 DSEE Results

DSEE testing of the ISL73141SEH was performed on three parts from Revision A silicon during the September test dates and on four parts from Revision B silicon during the April 2020 test dates. As previously stated, the difference in the two silicon revisions is minor metal layer changes.

Figure 2 shows the summary of the DSEE results for the ISL73141SEH Revision A devices tested during the September 2019 test dates. Two devices passed at AV_{CC} = 6.4V and one device failed at AV_{CC} = 6.5V by violating the conditions in Table 1 for AV_{CC} current. Of the two devices that passed at AV_{CC} = 6.4V, one device was tested and passed at AV_{CC} = 6.5V while the other was not tested beyond AV_{CC} = 6.4V.

Figure 3 shows the summary of the DSEE results for the ISL73141SEH Revision B devices (final released product) tested during the April 2020 test dates. Three of the four devices passed at AV_{CC} = 6.4V while the remaining device failed at AV_{CC} = 6.4V by violating the conditions in Table 1 for AV_{CC} current. Of the three devices that passed at AV_{CC} = 6.4V, two of them also passed at AV_{CC} = 6.5V while one failed at AV_{CC} = 6.5V.

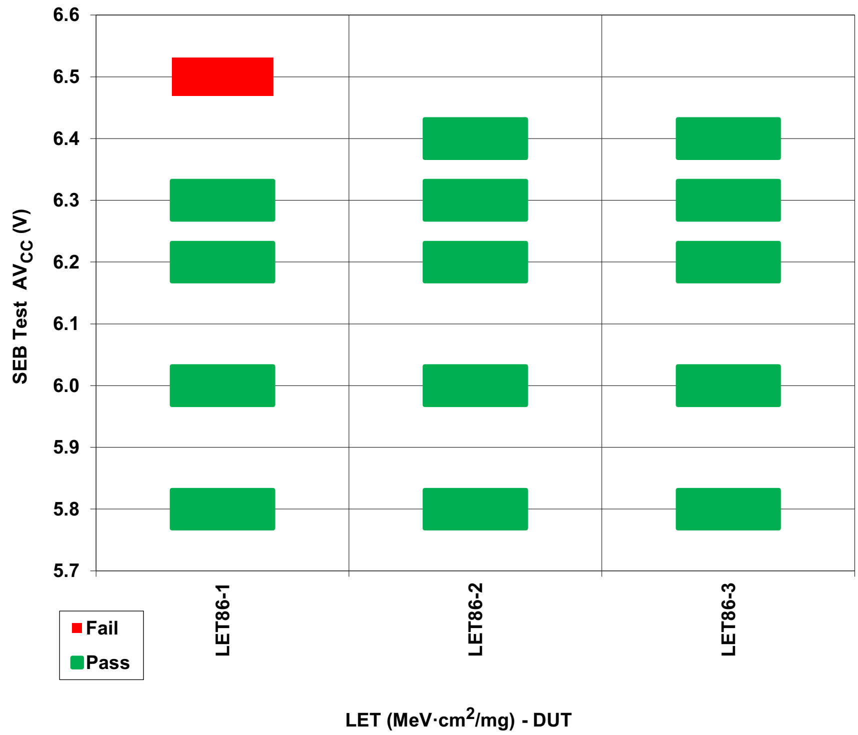

Figure 2. DSEE Testing Pass/Fail Summary - September 2019

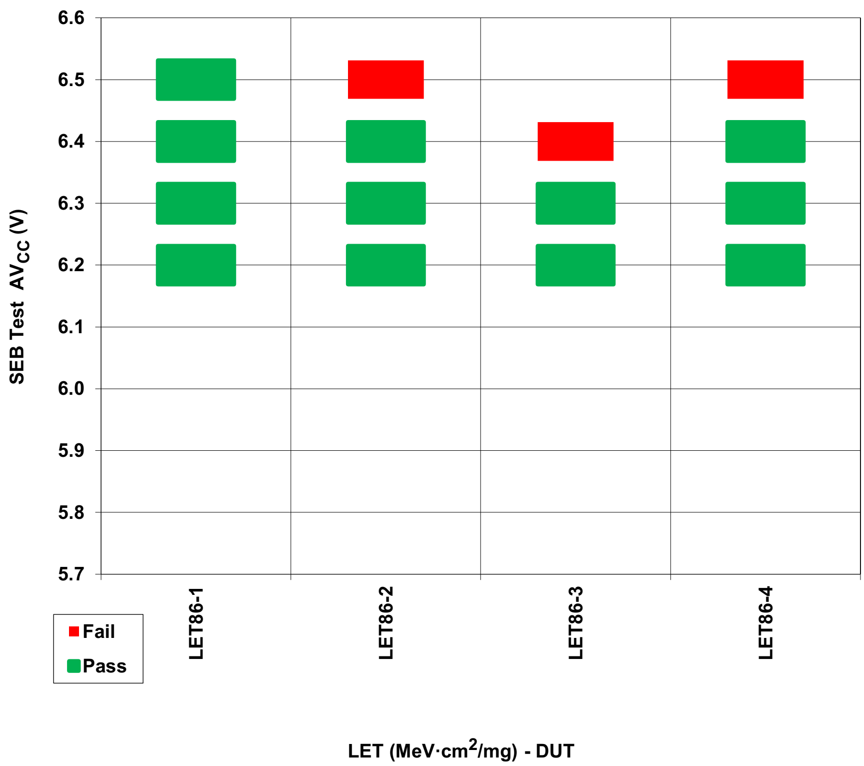

Figure 3. DSEE Testing Pass/Fail Summary - April 2020

DSEE of the ISL73141SEH was tested with normal incidence gold for 86MeV·cm²/mg at a die temperature of 125°C ±10°C, and DV_{CC}, V_{REF}, and AIN input voltages held constant at maximum values of 4.6V, 5.1V, and 5.1V. During the testing in September 2019, the AV_{CC} voltage was started at 5.8V and increased in 0.1V steps until DSEE was observed or 6.5V was reached. During the testing in April 2020, the AV_{CC} voltage was started at 6.2V and increased in 0.1V steps until DSEE was observed or 6.5V was reached. During both test dates, the sample rate was set to 1000ksps. Both before and after irradiation four parameters (Table 1) were monitored to look for signs of DSEE. The results of this testing for the ISL73141SEH part are presented for Revision A in Table 2 and Revision B (final) silicon in Table 3. Failures to the criteria in Table 1 are indicated with bold and red text. On the devices failing for AV_{CC} current during the April 2020 testing, there were also marginal failures for VREF current.

Table 2. ISL73141SEH Revision A DSEE Testing Results for Normal Incidence Gold at LET = 86MeV·cm²/mg and 125°C ±10°C Die Temperature - September 2019

Type-DUT	AV_{CC} (V)	I_{AVCC}		I_{DVCC}		I_{REF}		I_{AIN}	
		Pre (mA)	Delta (%)	Pre (mA)	Delta (%)	Pre (µA)	Delta (%)	Pre (µA)	Delta (%)
Rev A-1	5.8	15.97	0.06	3.34	0.00	123	0.00	76	0.00
	6.0	16.49	0.00	3.34	0.00	123	0.00	76	0.00
	6.2	17.03	0.06	3.33	0.00	123	0.00	76	0.00
	6.3	17.32	-0.11	3.32	0.30	123	0.00	76	0.00
	6.5	17.89	***235***	3.32	0.90	123	0.00	76	0.00
Rev A-2	5.8	15.93	0.00	3.20	0.00	129	0.00	69	0.00
	6.0	16.45	0.00	3.20	0.00	130	0.00	69	0.00
	6.2	16.99	0.06	3.20	0.00	130	0.00	69	0.00
	6.3	17.29	-0.06	3.20	-0.31	130	0.00	70	0.00
	6.4	17.58	-0.06	3.19	0.00	130	-0.78	70	0.00
Rev A-3	5.8	16.03	0.06	3.33	0.00	124	0.00	81	0.00
	6.0	16.56	0.06	3.33	-0.30	124	0.00	81	0.00
	6.2	17.11	0.12	3.31	0.00	124	0.00	81	0.00
	6.3	17.41	-0.11	3.31	0.00	124	0.00	81	0.00
	6.5	17.68	0.06	3.31	0.00	124	0.00	81	0.00

Note: Each entry represents change across an irradiation of $1x10^7$ion/cm².

Table 3. ISL73141SEH Revision B DSEE Testing Results for Normal Incidence Gold at LET = 86MeV·cm²/mg and 125°C ±10°C Die Temperature - April 2020

Type-DUT	AV_{CC} (V)	I_{AVCC}		I_{DVCC}		I_{REF}		I_{AIN}	
		Pre (mA)	Delta (%)	Pre (mA)	Delta (%)	Pre (µA)	Delta (%)	Pre (µA)	Delta (%)
Rev B-1	6.2	8.44	0.00	1.22	0.82	39	0.00	24.2	0.08
	6.3	8.57	0.00	1.21	0.00	39	0.00	24	0.00
	6.4	8.71	1.95	1.21	0.00	39	0.00	24	0.00
	6.5	9.05	1.44	1.21	0.00	39	0.00	24	0.00
Rev B-2	6.2	8.28	0.12	1.22	0.00	39	0.00	25	0.00
	6.3	8.42	0.12	1.22	0.00	39	0.00	25	0.00
	6.4	8.56	0.12	1.22	0.00	39	0.00	25	0.00
	6.5	8.71	**701**	1.22	1.63	39	0.00	25	0.00
Rev B-3	6.2	8.7	0.23	1.22	0.00	39	0.00	26	0.00
	6.3	8.85	9.6	1.22	0.00	39	0.00	26	0.00
	6.4	9.07	**486**	1.22	0.82	39	**12.8**	26	0.00

Table 3. ISL73141SEH Revision B DSEE Testing Results for Normal Incidence Gold at LET = 86MeV·cm²/mg and 125°C ±10°C Die Temperature - April 2020 (Continued)

Type-DUT	AV_{CC} (V)	I_{AVCC} Pre (mA)	I_{AVCC} Delta (%)	I_{DVCC} Pre (mA)	I_{DVCC} Delta (%)	I_{REF} Pre (µA)	I_{REF} Delta (%)	I_{AIN} Pre (µA)	I_{AIN} Delta (%)
Rev B-4	6.2	8.54	0.00	1.23	0.00	39	0.00	25	0.00
	6.3	8.68	0.12	1.23	0.00	39	0.00	25	0.00
	6.4	8.83	0.11	1.23	0.00	39	0.00	25	0.00
	6.5	8.98	589	1.23	1.63	39	15.4	25	0.00

Note: Each entry represents change across an irradiation of $1x10^7$ion/cm^2.

2.2 SET Results

Single event transient testing was performed on the ISL73141SEH under the conditions listed in Table 4. The sequence in which these conditions were implemented was in alternating style from one DUT to the next in the order of 1-2-3, then 3-2-1. This was implemented to detect any potential dependency on cumulative dose effects. The sample rates were changed depending on the AV_{CC} supply voltage. The ISL73141SEH does not support the 1000ksps operation for the 3.3V version of the product. To detect any potential AV_{CC} voltage related or sample rate related issues, the ADC was tested at AV_{CC} = 4.5V with 1000ksps in addition to a lower sample rate (500ksps or 750ksps). During Revision A testing, the ISL73141SEH was limited to 500ksps operation at AV_{CC} = 3.0V. However, Revision B silicon allowed for operation at 750ksps with AV_{CC} = 3.0V.

Table 4. ISL73141SEH SET Test Conditions

	Test Condition #1		Test Condition #2		Test Condition #3	
	Sept. 2019	April 2020	Sept. 2019	April 2020	Sept. 2019	April 2020
AV_{CC}	3.0V	3.0V	4.5V	4.5V	4.5V	4.5V
DV_{CC}	2.5V	2.5V	2.5V	2.5V	2.5V	2.5V
V_{REF}	3.0V	3.0V	3.0V	3.0V	3.0V	3.0V
AIN	1.5V	1.5V	1.5V	1.5V	1.5V	1.5V
Sample Rate	500ksps	750ksps	500ksps	750ksps	1000ksps	1000ksps

SET cross-sections were produced for each of these conditions. The results from September 2019 testing indicated the ISL73141SEH has a cumulative dose effect on the SET events. As the cumulative dose increases the number of SETs decrease. This is shown in Figure 4, Figure 5, and Figure 6. Because of the order of the test conditions, the second test performed in the sequence is always test condition number two. Test condition 1 alternates between being first and last in the test sequence as does test condition 3. In Figure 5 there is no difference between the 1st and 2nd DUT cross-sections section. These DUTs have the same amount of cumulative dose. However, in Figure 4 and Figure 6 the 2nd DUT has a lower cross-section in both cases. In both of these cases, the 2nd DUT has a higher cumulative dose indicating that the higher dose results in a reduction of the number of SETs. Based on the data from September 2019 testing, the total fluence was reduced and an increased number of DUTs lowered the cumulative dose to eliminate these effects. The difference in cumulative dose between the two test dates is given in Table 5. It can be seen that the dose rate was reduced significantly in the April 2020 SET testing. The cumulative dose in this table is an approximation based on the LET and total fluence in each run and is given as the amount seen by the device at the end of a given test run.

Table 5. ISL73141SEH Cumulative Dose for LET ≥ 20MeV·cm²/mg

Test Condition	LET = 20MeV·cm²/mg (krad)		LET = 43MeV·cm²/mg (krad)		LET = 86MeV·cm²/mg (krad)	
	Sept. 2019	April 2020	Sept. 2019	April 2020	Sept. 2019	April 2020
1 or 3 (1st DUT)	3.20	-	6.88	1.38	13.76	2.75
2	6.40	-	13.76	2.75	27.52	5.50
3 or 1 (2nd DUT)	9.60	-	20.64	4.13	41.28	8.26

The cross-sections between the two test dates also indicate some dependency on the sampling rate and AV_{CC} supply voltage. The 500ksps cross-sections show a saturation of 3.63×10^{-4}cm^2 to 5.93×10^{-4}cm^2. The 750ksps cross-sections show a saturation of 1.61×10^{-3}cm^2 to 2.23×10^{-3}cm^2 that moves closer to the 1000ksps cross-sections that range between 1.11×10^{-3}cm^2 to 1.17×10^{-3}cm^2. The cross-sections for the AV_{CC} = 4.5 condition and sample rates of 500ksps and 750ksps show a slightly lower saturation than the cross-sections for the AV_{CC} = 3.0V condition and the same sample rates.

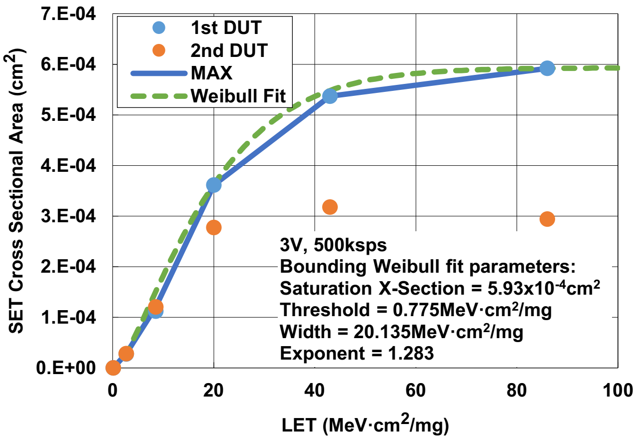

Figure 4. SET Cross-Section Test Condition #1 September 2019

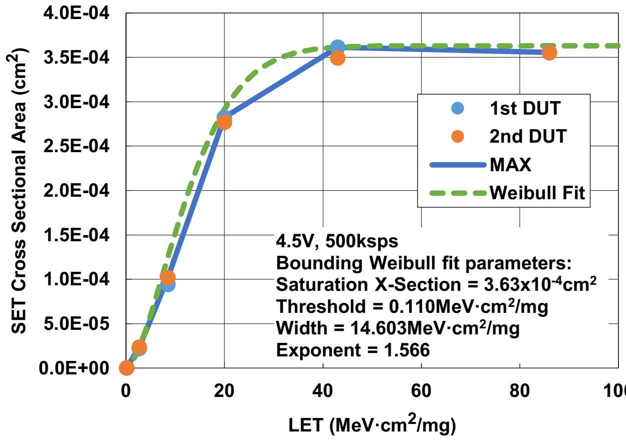

Figure 5. SET Cross-Section Test Condition #2 September 2019

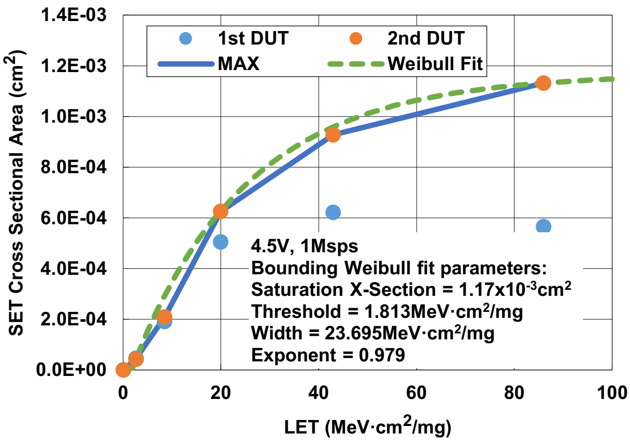

Figure 6. SET Cross-Section Test Condition #3 September 2019

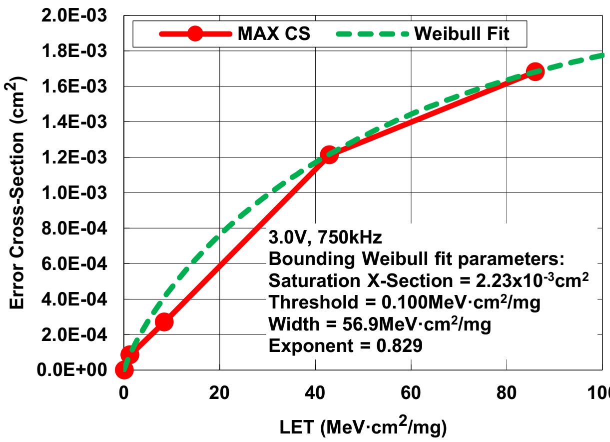

Figure 7. SET Cross-Section Test Condition #1 April 2020

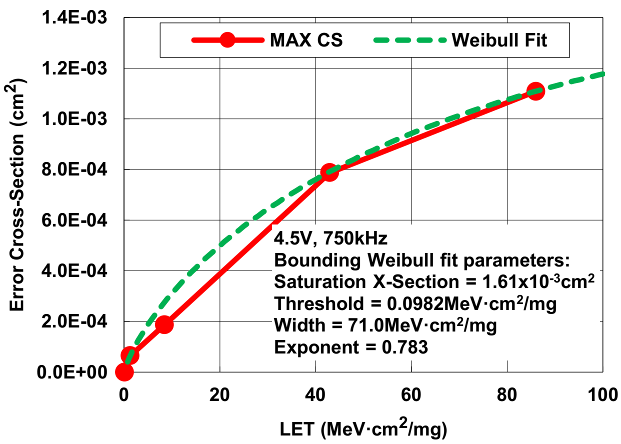

Figure 8. SET Cross-Section Test Condition #2 April 2020

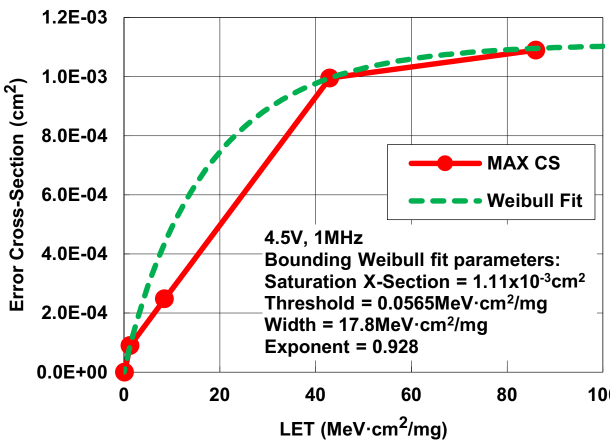

Figure 9. SET Cross-Section Test Condition #3 April 2020

The test data indicates that a majority of SET exhibited by the ISL73141SEH were under 100 codes in magnitude and lasted for a single sample. The results of the September 2019 test data shows that out of all SET that 94.92% were less than 100 codes in magnitude and 96.24% lasted for a single sample. With the reduced cumulative dose and higher SET count a more worst-case condition is exhibited by the April 2020 test data and yet the test data still shows that out of all SETs that 96.98% were less than 100 codes in magnitude and 91.47% lasted for a single sample. The data from both test dates shows that there are no SET that last longer than three consecutive samples. See Table 6 and Table 7 for more details. The two and three consecutive sample SET only occurred at higher LET values at and above 20MeV·cm^2/mg. There were no consecutive sample SETs observed at a LET below 8.5MeV·cm^2/mg.

Figure 10, Figure 11, and Figure 12 show the magnitude versus time of a typical set of SET test runs at an LET of 1.3MeV·cm^2/mg with different AV_{CC} values and sample rates. As can be seen, the delta between the expected code and the actual code for each SET is generally less than 50 codes. Across all devices tested at this LET the average magnitude of an SET is 14 codes. A typical set of SET test runs at an LET of 86MeV·cm^2/mg is shown in Figure 13, Figure 14, and Figure 14. At this LET there are a few SET that are near zero scale or full scale but the majority are within 100 codes of the expected value. The average magnitude of an SET at this LET was 109 codes. No SEFI were observed and the ADC returned to the expected code value range after every SET.

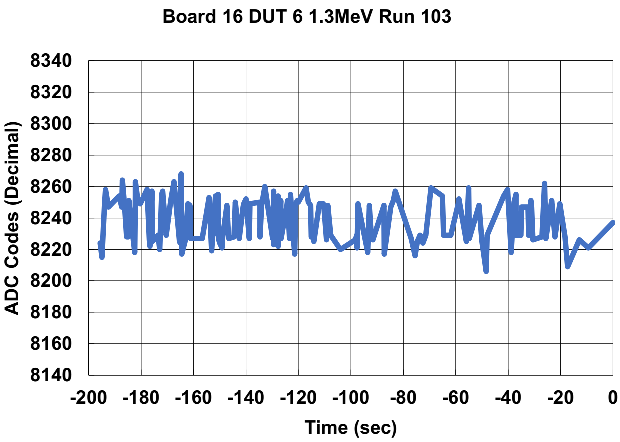

Figure 10. SET at AV_{CC} = 3.0V, f_S = 750ksps, and LET = 1.3

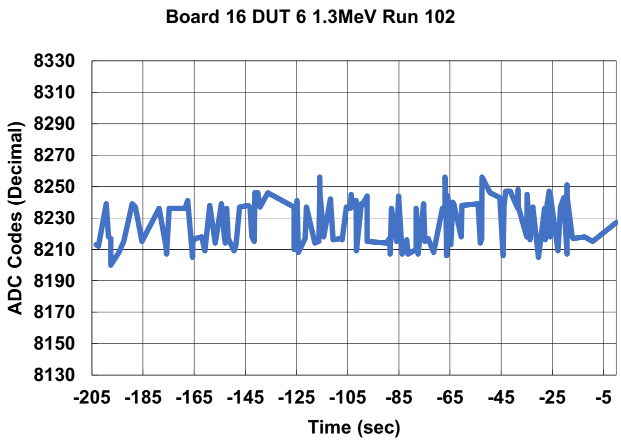

Figure 11. SET at AV_{CC} = 4.5V, f_S = 750ksps, and LET = 1.3

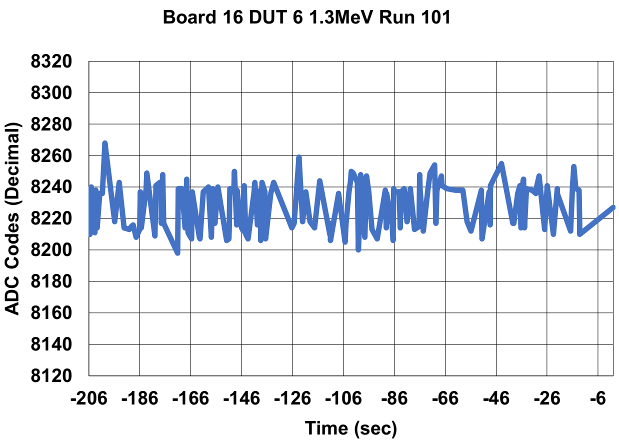

Figure 12. SET at AV_{CC} = 4.5V, f_S = 1000ksps, and LET = 1.3

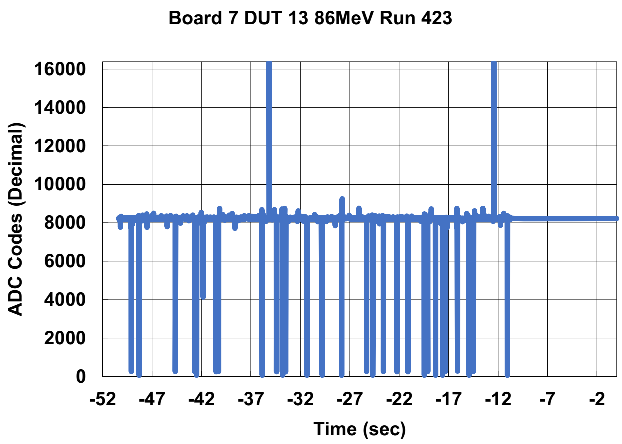

Figure 13. SET at AV_{CC} = 3.0V, f_S = 750ksps, and LET = 86

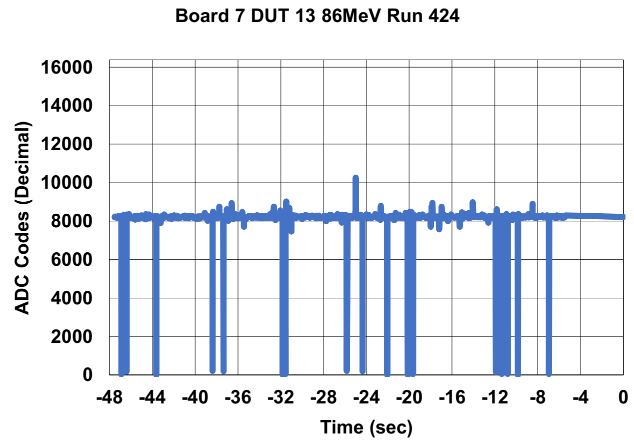

Figure 14. SET at AV_{CC} = 4.5V, f_S = 750ksps, and LET = 86

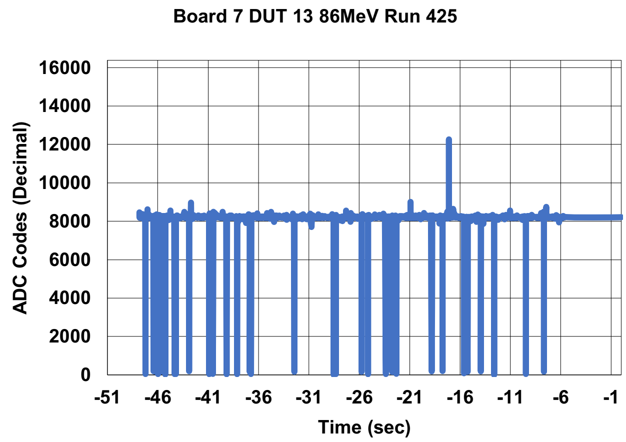

Figure 15. SET at AV_{CC} = 4.5V, f_S = 1000ksps, and LET = 86

For the SET test runs shown in Figure 13, Figure 14, and Figure 15 a histogram was generated and is shown in Figure 16. Even at the highest LET of 86MeV·cm^2/mg most of the SET are within 50 codes or less of the expected value. The expected code value is in the range of code 8192 so the max deviation should be less than 8500 codes even if the SET excursion is to zero scale or full scale. As can be seen in Figure 16 there are few SETs with code deltas that are in this range compared to the number of code deltas that are 50 codes are less.

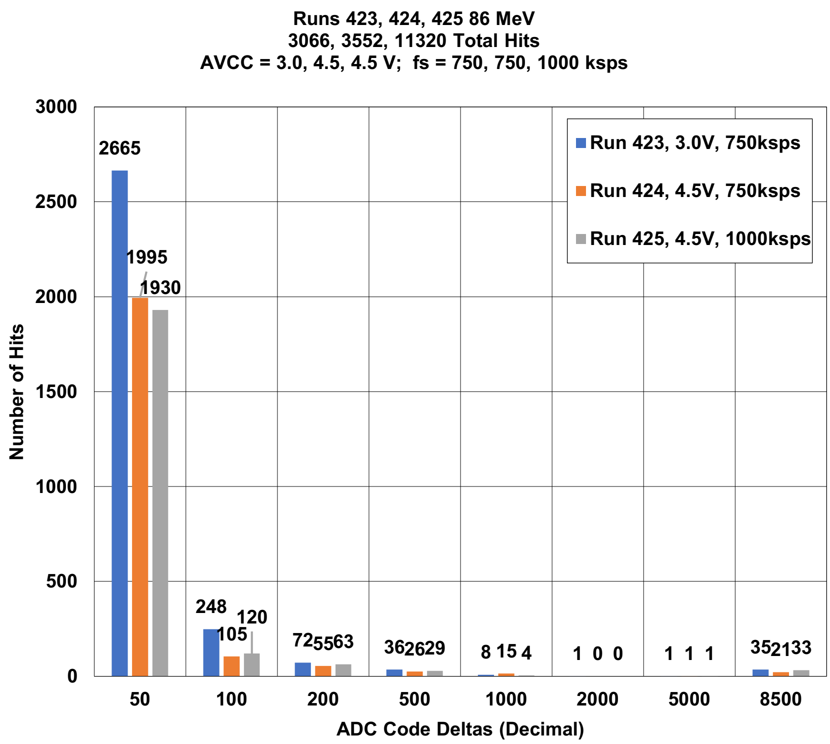

Figure 16. Output Code Delta Histogram for SET for Runs 423, 424, and 425 at 86MeV·cm^2/mg

All SET test runs from the two test dates are given in Table 6 (September 2019) and Table 7 (April 2020). Information is provided on the test conditions including DUT number, test number, LET, AV_{CC}, sample rate, total fluence, and approximate TID (total ionizing dose). The test results are given in terms of total SET, two consecutive sample SET, three consecutive sample SET, percentage of SET less than 100 codes in magnitude, percentage of single sample SET, and average code delta of all SET in a given test run.

During the SET testing in September 2019, the total fluence was 1x10^7 for all test runs. The ISL73141SEH devices were tested with a range of LET values from 86MeV·cm^2/mg (gold) down to 0.11MeV·cm^2/mg (helium) including 2.7MeV·cm^2/mg (neon), 8.5MeV·cm^2/mg (argon), 20MeV·cm^2/mg (copper), and 43MeV·cm^2/mg (silver) all at normal incidence. Data from the test runs at an LET of 0.11MeV·cm²/mg in September 2019 is not shown in Table 6 because no SET were observed at that LET. On evaluation of the test results from the SET runs in September 2019 it was found that there was some cumulative dose effect with the ISL73141SEH. As the cumulative dose (approximate TID in the table) increased, the number of SET decreased. This was pointed out in the discussion of the SET cross-sections as well and is evident in Figure 4 and Figure 6. Therefore, the SET test runs in April 2020 were adjusted accordingly to reduce the cumulative dose seen by a given ISL73141SEH device.

In the April 2020 SET testing the total fluence on test runs at LET values greater than 8.5MeV·cm²/mg (argon) was reduced to $2x10^6$ion/cm² to reduce cumulative dose. In addition, more ISL73141SEH devices completed the testing and further reduced the cumulative dose seen by each device. By implementing these factors into the test, a higher number of SETs were observed resulting in a condition where a worst-case cross-section of SET was achieved. Because the SET decreased with a higher cumulative dose, keeping the exposure of each DUT limited allows for the highest number of SET to be observed. The lineup of LET values used was also slightly adjusted to gain more visibility into the onset of SET at lower LET values. For the April 2020 testing at the following LET values was performed: 86MeV·cm²/mg (gold), 43MeV·cm²/mg (silver), 8.5MeV·cm²/mg (argon), 2.7MeV·cm²/mg (neon), 1.3MeV·cm²/mg (nitrogen), and 0.11MeV·cm²/mg (helium). No SET were observed at an LET of 0.11MeV·cm²/mg during the September 2019 testing, but a small number were observed during the April 2020 testing: 7 total SET (maximum delta of 16 codes) across 12 SET runs and 4 different ISL73141SEH devices. Testing was also performed at an LET of 1.3MeV·cm²/mg to gain more insight into SET onset. Because of the low magnitude of SET at 0.11MeV·cm²/mg it could be argued that the onset of an appreciable number of SET is at 1.3MeV·cm²/mg. Overall, the data shows that the number of SETs decrease as the LET decreases. In addition, the average magnitude of the SET observed stays relatively small across all LET even at the highest LET tested at 86MeV·cm²/mg. The ISL73141SEH returned to normal operation after every SET observed and no SEFIs were observed during any test run.

Table 6. ISL73141SEH Revision B SET Testing Results - September 2019

DUT	Run	LET (cm²/mg)	AV_{CC} (V)	Sample Rate (ksps)	Total Fluence (ion/cm²)	Approx. TID (krad)	Total SET	2 Consec. Sample SET	3 Consec. Sample SET	% SET <100 Codes	% SET Single Sample	Avg Code Delta
9	701	2.7	3.0	500	$1x10^7$	0.43	276	0	0	99.64	100.00	18.57
9	702	2.7	4.5	500	$1x10^7$	0.86	222	0	0	100.00	100.00	20.14
9	703	2.7	4.5	1000	$1x10^7$	1.3	459	0	0	99.78	100.00	18.31
10	704	2.7	4.5	1000	$1x10^7$	0.43	430	0	0	100.00	100.00	18.79
10	705	2.7	4.5	500	$1x10^7$	0.86	234	0	0	100.00	100.00	17.1
10	706	2.7	3.0	500	$1x10^7$	1.3	284	0	0	99.65	100.00	18.13
10	101	8.5	3.0	500	$1x10^7$	1.36	1121	0	0	97.95	100.00	22.27
10	102	8.5	4.5	500	$1x10^7$	2.72	942	0	0	97.56	100.00	22.31
10	103	8.5	4.5	1000	$1x10^7$	4.08	1913	0	0	98.27	100.00	21.41
9	104	8.5	4.5	1000	$1x10^7$	1.36	2089	0	0	98.47	100.00	21.13
9	105	8.5	4.5	500	$1x10^7$	2.72	1019	0	0	98.82	100.00	21.44
9	106	8.5	3.0	500	$1x10^7$	4.08	1202	0	0	98.17	100.00	22.06
9	201	20	3.0	500	$1x10^7$	3.2	3618	0	0	97.87	100.00	34.63
9	202	20	4.5	500	$1x10^7$	6.4	2824	0	0	97.77	100.00	23.67
9	203	20	4.5	1000	$1x10^7$	9.6	5057	166	0	96.93	96.72	31.53
10	204	20	4.5	1000	$1x10^7$	3.2	6257	602	0	97.57	90.38	26.98
10	205	20	4.5	500	$1x10^7$	6.4	2769	0	0	96.93	100.00	33.46
10	206	20	3.0	500	$1x10^7$	9.6	2774	0	0	96.29	100.00	35.38
7	301	43	3.0	500	$1x10^7$	6.88	5373	2	0	96.13	99.96	45.82

Table 6. ISL73141SEH Revision B SET Testing Results - September 2019 (Continued)

DUT	Run	LET (cm^2/mg)	AV_{CC} (V)	Sample Rate (ksps)	Total Fluence (ion/cm^2)	Approx. TID (krad)	Total SET	2 Consec. Sample SET	3 Consec. Sample SET	% SET <100 Codes	% SET Single Sample	Avg Code Delta
7	302	43	4.5	500	$1x10^7$	13.76	3614	0	0	94.91	100.00	54.78
7	303	43	4.5	1000	$1x10^7$	20.64	6222	150	0	93.56	97.59	45.84
8	304	43	4.5	1000	$1x10^7$	6.88	9286	1228	0	95.35	86.78	39.81
8	305	43	4.5	500	$1x10^7$	13.76	3495	0	0	95.39	100.00	45.24
8	306	43	3.0	500	$1x10^7$	20.64	3178	0	0	94.90	100.00	62.28
6	401	86	3.0	500	$1x10^7$	13.76	5919	26	0	93.82	99.56	80.5
6	402	86	4.5	500	$1x10^7$	27.52	3554	0	0	90.77	100.00	81.04
6	403	86	4.5	1000	$1x10^7$	41.28	5656	6	0	88.30	99.89	78.8
5	404/405	86	4.5	1000	$1x10^7$	13.76	11320	1458	30	93.87	86.86	52.24
5	406	86	4.5	500	$1x10^7$	27.52	3552	0	0	92.15	100.00	95.78
5	407	86	3.0	500	$1x10^7$	41.28	2943	0	0	89.77	100.00	138.91

Table 7. ISL73141SEH Revision B SET Testing Results - April 2020

DUT	Run	LET (cm^2/mg)	AV_{CC} (V)	Sample Rate (ksps)	Total Fluence (ion/cm^2)	Approx. TID (krad)	Total SET	2 Consec. Sample SET	3 Consec. Sample SET	% SET <100 Codes	% SET Single Sample	Avg Code Delta
19	801	0.11	4.5	1000	$1x10^7$	8.88	0	0	0	0	0	0
19	802	0.11	4.5	750	$1x10^7$	8.87	0	0	0	0	0	0
19	803	0.11	3.0	750	$1x10^7$	8.85	0	0	0	0	0	0
5	804	0.11	3.0	750	$1x10^7$	8.88	0	0	0	0	0	0
5	805	0.11	4.5	750	$1x10^7$	8.87	0	0	0	0	0	0
5	806	0.11	4.5	1000	$1x10^7$	8.85	0	0	0	0	0	0
4	807	0.11	4.5	1000	$1x10^7$	8.88	2	0	0	100.00	100.00	14
4	808	0.11	4.5	750	$1x10^7$	8.87	0	0	0	0	0	0
4	809	0.11	3.0	750	$1x10^7$	8.85	1	0	0	100.00	100.00	16
6	810	0.11	3.0	750	$1x10^7$	8.88	0	0	0	0	0	0
6	811	0.11	4.5	750	$1x10^7$	8.87	3	0	0	100.00	100.00	12
6	812	0.11	4.5	1000	$1x10^7$	8.85	1	0	0	100.00	100.00	12
6	101	1.3	4.5	1000	$1x10^7$	8.42	170	0	0	100.00	100.00	14.18
6	102	1.3	4.5	750	$1x10^7$	8.62	130	0	0	100.00	100.00	13.86
6	103	1.3	3.0	750	$1x10^7$	8.83	157	0	0	100.00	100.00	13.55
4	104	1.3	3.0	750	$1x10^7$	8.42	160	0	0	100.00	100.00	13.84
4	105	1.3	4.5	750	$1x10^7$	8.62	129	0	0	100.00	100.00	14.64
4	106	1.3	4.5	1000	$1x10^7$	8.83	180	0	0	100.00	100.00	13.5
5	107	1.3	3.0	750	$1x10^7$	8.42	144	0	0	100.00	100.00	14.5
5	108	1.3	4.5	750	$1x10^7$	8.62	119	0	0	100.00	100.00	13.88
5	109	1.3	4.5	1000	$1x10^7$	8.83	174	0	0	100.00	100.00	14.31
19	110	1.3	4.5	1000	$1x10^7$	8.42	147	0	0	100.00	100.00	14.65
19	111	1.3	4.5	750	$1x10^7$	8.62	102	0	0	100.00	100.00	13.68
19	112	1.3	3.0	750	$1x10^7$	8.83	150	0	0	100.00	100.00	13.85

Table 7. ISL73141SEH Revision B SET Testing Results - April 2020 (Continued)

DUT	Run	LET (cm^2/mg)	AV_{CC} (V)	Sample Rate (ksps)	Total Fluence (ion/cm^2)	Approx. TID (krad)	Total SET	2 Consec. Sample SET	3 Consec. Sample SET	% SET <100 Codes	% SET Single Sample	Avg Code Delta
5	201	8.5	3.0	750	$1x10^7$	5.49	2626	2	0	99.16	99.92	18.75
5	202	8.5	4.5	750	$1x10^7$	6.85	1831	0	0	99.45	100.00	18.5
5	203	8.5	4.5	1000	$1x10^7$	8.21	2394	9	0	98.96	99.62	19.2
19	204	8.5	4.5	1000	$1x10^7$	5.49	2593	35	0	99.00	98.65	19.41
19	205	8.5	4.5	750	$1x10^7$	6.85	1869	0	0	99.30	100.00	19.18
19	206	8.5	3.0	750	$1x10^7$	8.21	2403	0	0	99.33	100.00	18.68
4	207	8.5	3.0	750	$1x10^7$	5.49	2521	0	0	99.05	100.00	19.21
4	208	8.5	4.5	750	$1x10^7$	6.85	1816	0	0	99.34	100.00	18.31
4	209	8.5	4.5	1000	$1x10^7$	8.21	2389	16	0	98.83	99.33	19.17
6	210	8.5	4.5	1000	$1x10^7$	5.49	2708	74	0	99.22	97.27	18.26
6	211	8.5	4.5	750	$1x10^7$	6.85	1774	0	0	99.32	100.00	19.1
6	212	8.5	3.0	750	$1x10^7$	8.21	2475	1	0	99.15	99.96	19.68
15	301	43	3.0	750	$2x10^6$	1.38	1990	249	0	97.44	87.49	42.08
15	302	43	4.5	750	$2x10^6$	2.75	1510	73	0	96.95	95.17	39.08
15	303	43	4.5	1000	$2x10^6$	4.13	1779	257	0	95.90	85.55	43.03
22	304	43	4.5	1000	$2x10^6$	1.38	2425	611	33	97.53	73.44	25.86
22	305	43	4.5	750	$2x10^6$	2.75	1575	85	0	97.14	94.60	32.81
22	306	43	3.0	750	$2x10^6$	4.13	1990	249	0	97.04	87.49	42.39
9	307	43	3.0	750	$2x10^6$	1.38	2116	294	0	97.16	86.11	39.13
9	308	43	4.5	750	$2x10^6$	2.75	1486	78	0	97.31	94.75	43.52
9	309	43	4.5	1000	$2x10^6$	4.13	1846	270	0	97.07	85.37	36.49
14	310	43	4.5	1000	$2x10^6$	1.38	2083	462	0	96.54	77.82	28.93
14	311	43	4.5	750	$2x10^6$	2.75	1496	57	0	96.86	96.19	29.41
14	312	43	3.0	750	$2x10^6$	4.13	1624	77	0	96.37	95.26	60.98
13	423	86	3.0	750	$2x10^6$	2.75	3066	570	3	95.01	81.31	122.01
13	424	86	4.5	750	$2x10^6$	5.50	2217	159	1	94.68	92.78	108.52
13	425	86	4.5	1000	$2x10^6$	8.26	2179	293	13	94.03	85.96	154.39
21	426	86	4.5	1000	$2x10^6$	2.75	3337	802	37	94.01	74.86	209.09
21	427	86	4.5	750	$2x10^6$	5.50	1420	43	0	92.46	96.97	297.34
21	428	86	3.0	750	$2x10^6$	8.26	1336	3	0	92.22	99.78	115.2
23	451	86	3.0	750	$2x10^6$	2.75	2865	528	5	95.92	81.40	49.64
23	452	86	4.5	750	$2x10^6$	5.50	1692	81	0	95.80	95.21	43.74
23	453	86	4.5	1000	$2x10^6$	8.26	1953	203	0	93.75	89.61	58.64
24	454	86	4.5	1000	$2x10^6$	2.75	3363	820	30	95.51	74.72	42.85
24	455	86	4.5	750	$2x10^6$	5.50	1731	80	0	95.49	95.38	38.57
24	456	86	3.0	750	$2x10^6$	8.26	1609	40	0	93.47	97.51	63.52

3. SET Mitigation Options

The ISL73141SEH experiences SET when exposed to irradiation. These SET are low in magnitude on average and mostly last for a single sample. To mitigate these events some possible options are presented in this report.

One option is to collect a large number of samples (such as 10000 or larger) and average the samples collected to reduce the effects of a SET within those samples. Averaging a large number of samples lowers the impact of any SET that may be present in the collected data. The application would dictate the number of samples required to reduce the effects and a potential SET below any appreciable system-level effect.

In an application where a known range of values are expected, a second option is to discount a set of samples if the sample(s) within a given acquisition of data is outside a defined window. This method is similar to the detection of SET presented herein. In this case, if samples are collected outside the expected range, it is disregarded and another acquisition of data occurs. In the unlikely event that repeated data acquisitions show a SET then another option can be used.

In this third option, a combination of the first two options is a potential solution. This option collects a large number of samples (such as 10000) and throw s away any sample beyond an application based threshold window, and averages the remaining samples. If a set of sample data is collected with an expected value of 8200 and an expected range of 8150 to 8250, any code outside of this range is thrown out while the remaining samples are recorded.

4. Discussion and Conclusions

The ISL73141SEH proved to be DSEE immune up to an AV_{CC} supply voltage of 6.3V for irradiation with normal incidence Au for 86MeV·cm^2/mg. The testing was done with a die temperature of 125°C ±10°C. A DSEE event was only observed on one DUT at AV_{CC} = 6.5V during the September 2019 testing where the AV_{CC} domain experienced a destructive latch-up. During the April 2020 testing, DSEE events were observed on two DUTs at AV_{CC} = 6.5V and one DUT at AV_{CC} = 6.4V. These particular DUTs experienced destructive latch-up conditions on the AV_{CC} domain in addition to marginally failing increased current on the REF input. This results in a maximum allowable AV_{CC} voltage of 6.3V.

The ISL73141SEH exhibited no SEFIs and had mostly single sample low magnitude SETs. A cumulative dose effect exists with the device that results in a reduction of the number of SETs as the total ionizing dose increases. Only a small number of SETs were observed at a LET of 0.11MeV·cm^2/mg during the April 2020 testing (7 total SETs across 12 runs) and none occurred during the September 2019 testing. This implies that the onset of any appreciable amount of SET occurs at a LET of 1.3MeV·cm^2/mg. The SET remains at a relatively low average magnitude up to a LET of 86MeV·cm^2/mg. The September 2019 SET data shows out of all SET observed 94.92% were less than 100 codes in magnitude and 96.24% lasted for a single sample. The April 2020 test data shows that out of all SET that 96.98% were less than 100 codes in magnitude and 91.47% lasted for a single sample. The SET data exhibits that the ISL73141SEH does not experience large magnitude SET on average and that when a SET occurs, the device recovers after one sample the majority of the time with no event lasting longer than three samples.

5. Revision History

Rev.	Date	Description
1.02	Jan 3, 2024	Updated SET Results section.
1.01	Mar 30, 2022	Updated Part Description on page 1. Added TOC.
1.00	Aug 21, 2020	initial release

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