ISL71840SEH, ISL73840SEH

Single-Event Effects (SEE) Testing

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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 Gate Rupture (SEGR), and Single-Event Burnout (SEB). Single-event effects 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 Intersil ISL71840SEH 16:1 multiplexer (MUX) designed for space applications. The results apply equally to the ISL73840SEH.

Product Description

The ISL71840SEH is a 16:1 analog multiplexer (MUX) that operates with supply voltages from ±10.8V to ±16.5V and input overvoltage capability to ±35V. The part is also “cold spare” capable; i.e., inputs of an unpowered part do not leak more than 1µA to ±35V. The ISL71840SEH is fabricated in a proprietary, Intersil-bonded wafer SOI BiCMOS process. The ISL73840SEH is the same silicon part as the ISL71840SEH. Therefore, the SEE results apply equally to both parts.

Related Literature

- For a full list of related documents, visit our website
  - ISL71840SEH, ISL73840SEH product page

SEE Test Objectives

The ISL71840SEH was tested to determine its susceptibility to destructive single-event effects (SEGR and SEB, collectively referred to as SEB) and to characterize its Single-Event Transient (SET) behavior over various conditions and ion Linear Energy Transfer (LET) levels. The ISL71840SEH parts tested came from lot J67669.1, wafer #3, manufactured on Intersil’s proprietary P6SOI process.

SEE Test Facility

Testing was performed at the Texas A&M University (TAMU) Cyclotron Institute heavy ion facility. This facility is coupled to a K500 super-conducting cyclotron, which is capable of generating a wide range of test particles with the various energy, flux, and fluence levels needed for advanced radiation testing. Details on the test facility can be found on the TAMU Cyclotron website. Testing was carried out on December 15th and 16th of 2014.

SEE Test Set-Up

SEE testing was carried out with the sample in an active configuration. A schematic of the ISL71840SEH SEE test fixture is shown in Figure 1. The test circuit is configured to accept variable supply voltages and two groupings of variable input voltages. The addressing of input IN13 is accomplished with either logic threshold inputs (SW1 closed for 16% and 80% of VREF) or with railed logic inputs (SW1 open for VREF and GND). The output is set to half of VIN13-GND by a resistor divider formed from VIN13 to GND.

The ISL71840SEH samples were in standard ceramic flatpack packages without lids and were assembled on boards that allowed two parts to be irradiated at one time. A 20-foot coaxial cable was used to connect the test fixture to a switch box in the control room, which contained all of the monitoring equipment. The switch box allowed the two test circuits to be controlled and monitored remotely.

Digital multimeters were used to monitor pertinent voltages and currents. LeCroy WaveRunner 4-channel digital oscilloscopes were used to capture and store SET traces at V_{OUT} that exceeded the oscilloscopes’ ±20mV AC trigger setting.

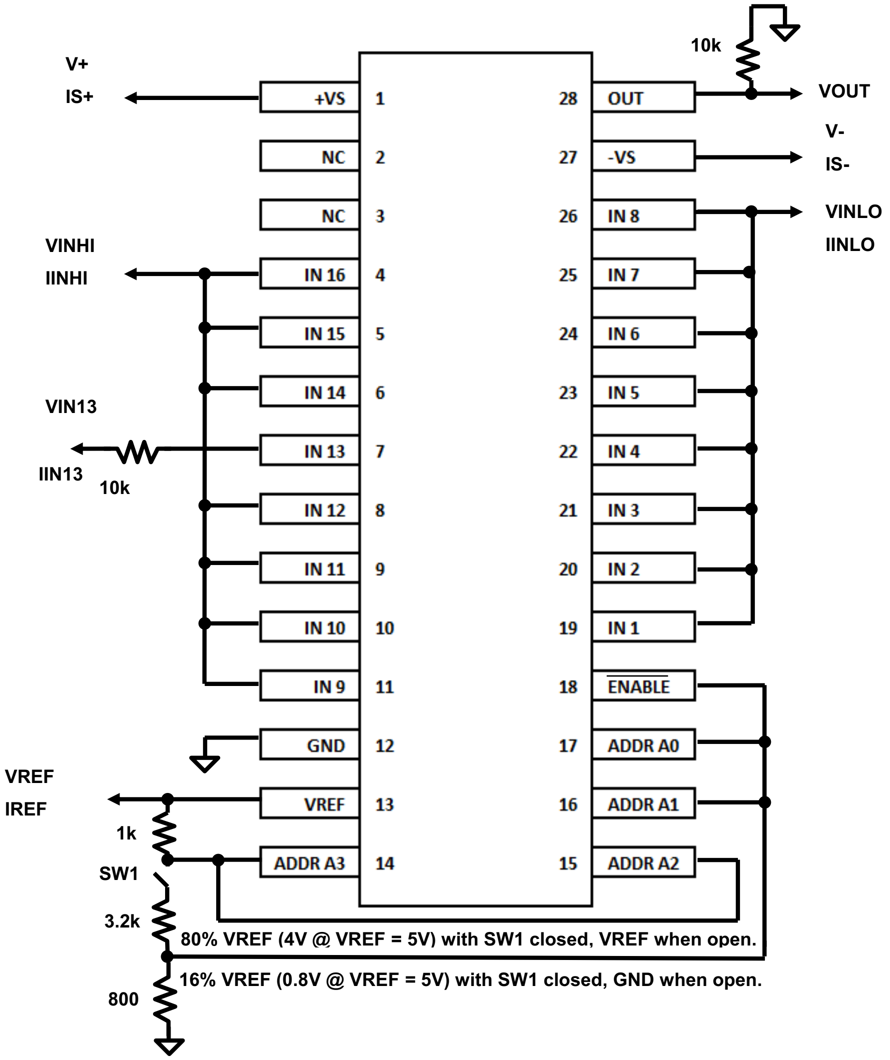


FIGURE 1. SCHEMATIC OF THE ISL71840SEH SEE TESTING CONFIGURATION

SEE Damage (SEB) Testing

For the destructive SEE (SEB) tests, conditions were selected to maximize the electrical and thermal stresses on the Device Under Test (DUT), thus ensuring worst-case conditions. The supply voltages were set to the part's absolute maximum rating of ±20V. The input voltages were set to ±17V and ±35V to stress the switches at relevant extreme conditions. Case temperature was maintained at +125°C by controlling the current flowing into a resistive heater bonded to the underside of the board. Four DUTs were irradiated with 2.954GeV Au ions at normal incidence, resulting in a surface LET = 86.4MeV • cm^2/mg. The normal range into silicon for these Au ions after 30mm of air is about 118µm with a Bragg peak range of 53µm. More information can be found on the TAMU Cyclotron website. These conditions guaranteed ions transited all active device volume in this SOI process (about 10µm depth). The switch SW1 in the OPEN condition provided railed (GND and VREF) enable and address lines to the parts. Table 1 summarizes the SEB testing conditions.

TABLE 1. SEB TESTING CONDITIONS

NUMBER OF TESTS	EFFECTIVE LET (MeV • cm^2/ mg)	SW1	±VS (V)	VIN13	VINLO	VINHI	V_{REF} (V)
Test 1	86.4	OPEN	±20	1.0	-17.00	17.00	+20
Test 2	86.4	OPEN	±20	1.0	-35.00	35.00	+20

NOTE: Exposure was with 2.954GeV Au at 0° incidence for LET = 86MeV • cm^2/mg to a fluence of $5x10^6$ ions/cm^2 at case temperature of +125°C for each test.

The set of parameters monitored to look for indications of device damage along with the actual measurements appear in Table 2. The currents represent the sum of the currents for two DUTs as called out in Table 2. In all cases, the changes in parameters were within the 8% change of measurement repeatability without the beam and so it was concluded that there was no permanent damage sustained by the parts for any of the SEB testing completed. Each irradiation was carried out to a fluence of 5x10^6 ions/cm^2. From this data the ISL71840SEH is deemed to have an SEB cross section of less than 1.5x10^{-7}cm^2 to a confidence of 95% for either test case. Combining all the results for both tests drives the SEB cross section down to 7.5x10^{-8} cm^2 at a 95% confidence.

TABLE 2. SEB MONITOR PARAMETERS FOR TESTING AT LET∠0° = 86.4 MeV•cm^2/mg and T_{CASE} = +125°C

DELTA FAILURE CRITERIA			0.005	8%	8%	8%
MONITORED PARAMETER			VOUT (V)	IS+ (µA)	IS- (µA)	I_{REF} (µA)
DUT1 + DUT2	Test 1	Pre	0.000	516	512	339
		Post	0.000	513	512	340
	Test 2	Pre	0.000	501	499	343
		Post	0.000	495	495	342
DUT3 + DUT4	Test 1	Pre	0.000	578	574	337
		Post	0.000	536	536	337
	Test 2	Pre	0.000	485	482	337
		Post	0.000	483	483	338

NOTE: Each irradiation was to a fluence of 5x10^6 ions/cm^2. No parameter deltas exceeded failure criteria.

SET Testing of ISL71840SEH 16:1 Analog MUX

SET testing was done on four samples of the ISL71840SEH. Testing started with gold (Au) at LET∠0° = 86.4MeV•cm^2/mg and with the SET detection threshold set to ±20mV deviation AC-coupled on V_{OUT}. Subsequently, the test LET was reduced to 43MeV•cm^2/mg (Ag at 0° incidence) and then finally to 20MeV•cm^2/mg (Cu at 0° incidence). Two separate conditions as shown in Table 3 were applied to each of the four parts tested.

TABLE 3. SET TESTING CONDITIONS

NUMBER OF TESTS	SW1	VS± (V)	VIN13	VINLO (V)	VINHI (V)	V_{REF} (V)
Test 1	CLOSED	±10.8	1.00	-10.8	10.8	4.5
Test 2	CLOSED	±16.5	1.00	-16.5	16.5	4.5

The first test, tests the part operating at the bottom of the recommended supply voltage range, ±10.8V. The second test exercises the part at the maximum of the supply voltage range, ±16.5V. In both cases the VREF is set to the minimum of the recommended operating range of 4.5V to minimize the noise margin in the addressing circuits. The lower noise margins makes the addressing most susceptible to a SEE that could lead to an address change SET.

Table 4 on page 4 summarizes the SET counts for each test by DUT and then reports the nominal SET cross section for the complement of all four DUTs. The cross sections reported are the nominal found by dividing the event counts by the total fluence generating those counts.

TABLE 4. ±20mV SET COUNTS FOR TESTING OF THE ISL71840SEH

TEST LET AND FLUENCE PER TEST	TEST CONFIGURATIONS	DUT1 ±20mV EVENT COUNTS	DUT2 ±20mV EVENT COUNTS	DUT3 ±20mV EVENT COUNTS	DUT4 ±20mV EVENT COUNTS	TOTAL CROSS SECTION (cm^2)	COMBINED TEST CROSS SECTION (cm^2)
LET = 86 4x10^{6}	Test 1, ±10.8 V	1153	1024	1332	1116	2.89x10^{-4}	3.23x10^{-4}
	Test 2, ±16.5 V	1524	1371	1275	1561	3.58x10^{-4}	
LET = 43 4x10^{6}	Test 1, ±10.8 V	91	79	62	72	1.90x10^{-5}	2.08x10^{-5}
	Test 2, ±16.5 V	78	80	86	71	2.25x10^{-5}	
LET = 20 4x10^{6}	Test 1, ±10.8 V	3	0	-	-	3.75x10^{-7}	3.75x10^{-7}
	Test 2, ±16.5 V	1	2	-	-	3.75x10^{-7}	

NOTE: LET listed in MeV•cm^2/mg and fluence in ions/cm^2.

Post processing of the captured SET oscilloscope traces generated the composite plots in Figures 2A through 3D for the LET = 86.4 MeV•cm^2/mg case. These plots show the composite of the 20 largest and 20 longest for each sense of the extreme deviation (positive and negative), so they reflect at most, the worst 80 SETs observed in the run. Figures 2A through 3D are truncated at ±0.2V, as that was the limit of the oscilloscope range; this range was necessary to allow triggering at ±0.020V. The SET shows a step deviation, either positive or negative, followed by an exponential decay. The magnitudes of the SET steps are within about ±0.15V, except for one instance, and do not appear to indicate any change of the MUX addressing state driving V_{OUT} immediately toward either ±10.8V in Figures 2A through 2D or ±16.5V in Figures 3A through 3D. This is expected as redundancy was applied to the address decoding such that a SET causing an addressing change should be impossible.

The differences between the DUTs in Figures 2A through 2D SET plots seems more a function of the rarity of the largest and longest events selected for presentation in the plots than different fundamental behaviors of the DUTs. For example, the single largest event seen on DUT4 (lower right plot of Figures 2A through 2D, exceeding -0.2V) likely could have occurred in any of the four DUTs, but random chance placed that single event in DUT4. The similarity of the bulk of the plotted events combined with this statistical sampling interpretation of the rare events makes it reasonable to view the four DUTs as representing the same general underlying SET behavior.

The equivalence of the results in Figures 4A through 4D is much more readily apparent. All four DUTs produced composites that look very similar.

Composite Plots

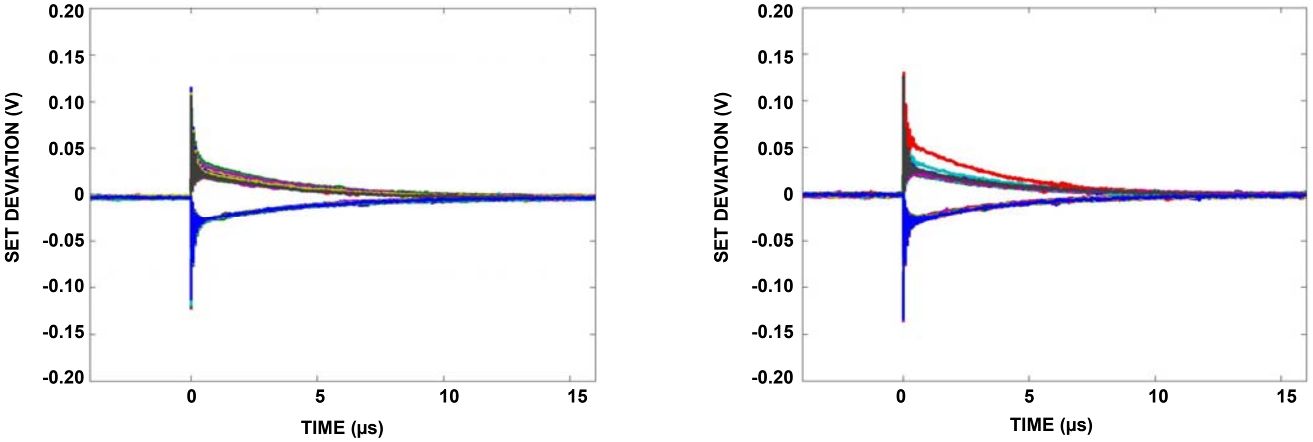


FIGURE 2A. DUT1, RUN 401

FIGURE 2B. DUT2, RUN 401

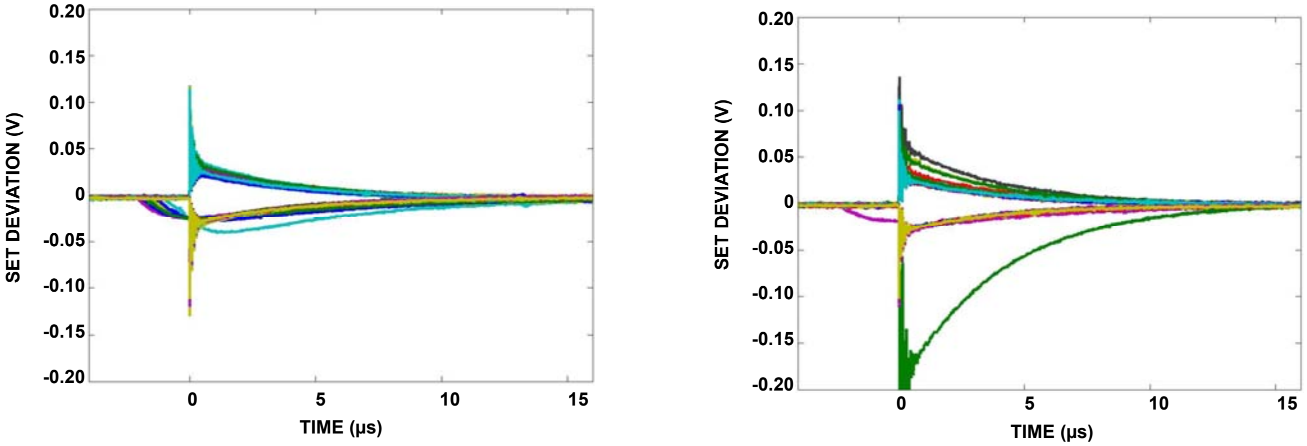


FIGURE 2C. DUT3, RUN 403

FIGURE 2D. DUT4, RUN 403

FIGURE 2. Figures 2A through 2D are composite plots of extreme SET for LET = 86.4MeV • cm^2/mg for DUT1 through DUT4 with ±10.8 V supplies. Each run was to have a fluence of $4.0x10^6$ ions/cm^2. Post processing selected the 20 largest and longest SET in both positive and negative deviations; not all of 80 such plots were unique. The oscilloscope setting limited the captured deviation range to ±0.2V.

Composite Plots (Continued)

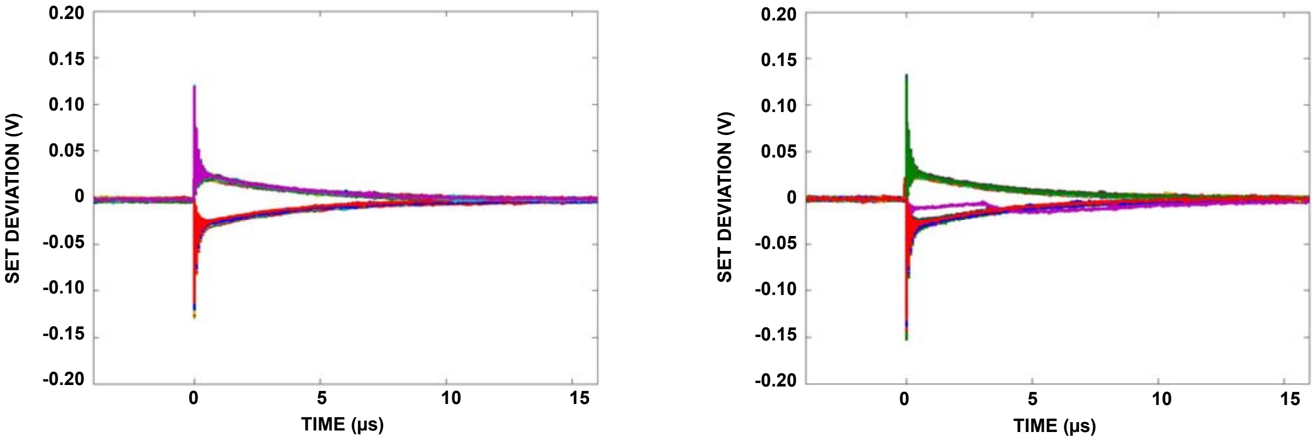


FIGURE 3A. DUT1, RUN 402

FIGURE 3B. DUT2, RUN 402

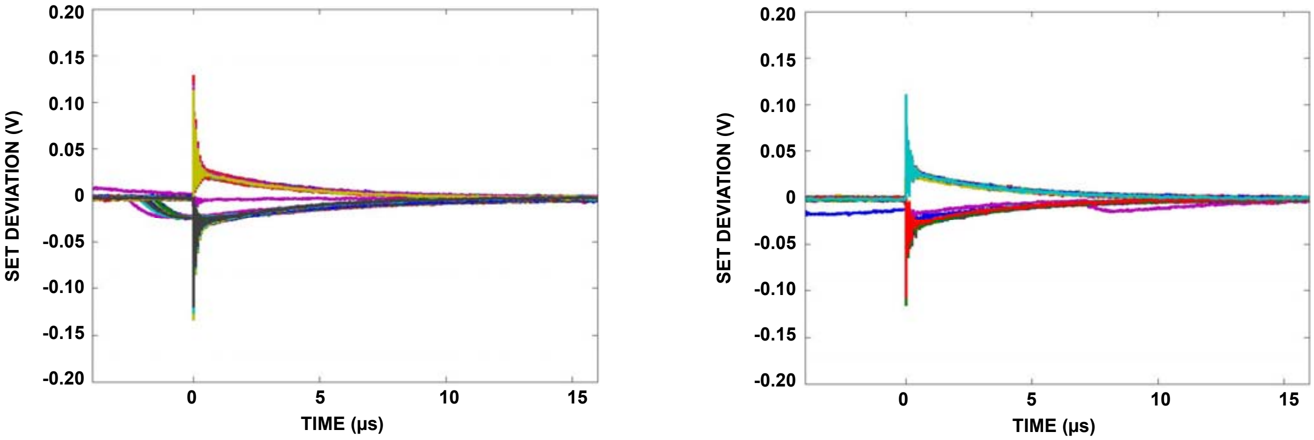


FIGURE 3C. DUT3, RUN 404

FIGURE 3D. DUT4, RUN 404

FIGURE 3. Figures 3A through 3D are composite plots of SET for LET = 86.4MeV•cm^2/mg for DUT1 through DUT4 and Test 2, ±16.5V supplies. Each run was to a fluence of 4.0x10^6 ions/cm^2. Post processing selected the 20 largest and longest SET in both positive and negative deviations; not all of the 80 such plots were unique. The oscilloscope setting limited the deviation range to ±0.2V.

Composite Plots (Continued)

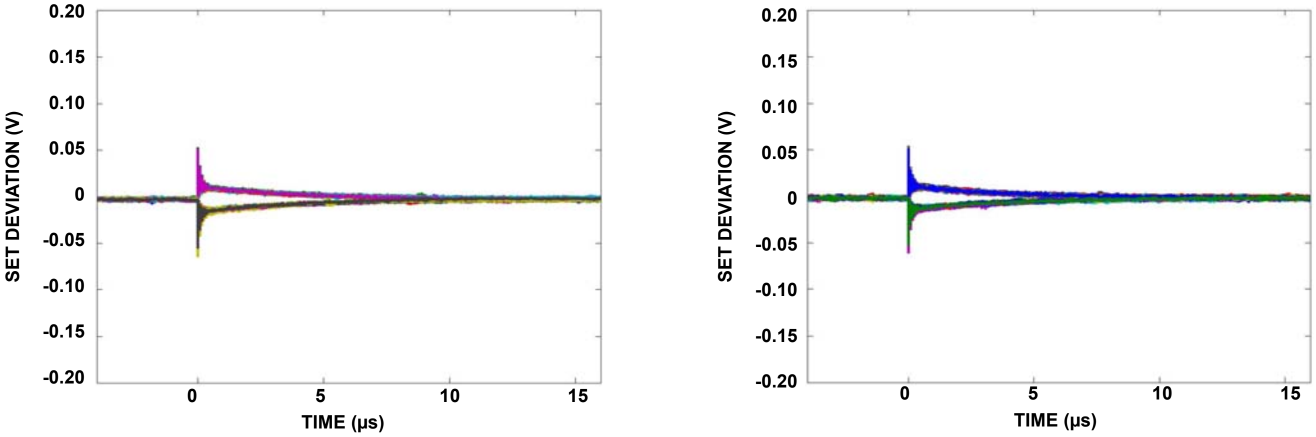


FIGURE 4A. DUT1, RUN 301

FIGURE 4B. DUT2, RUN 301

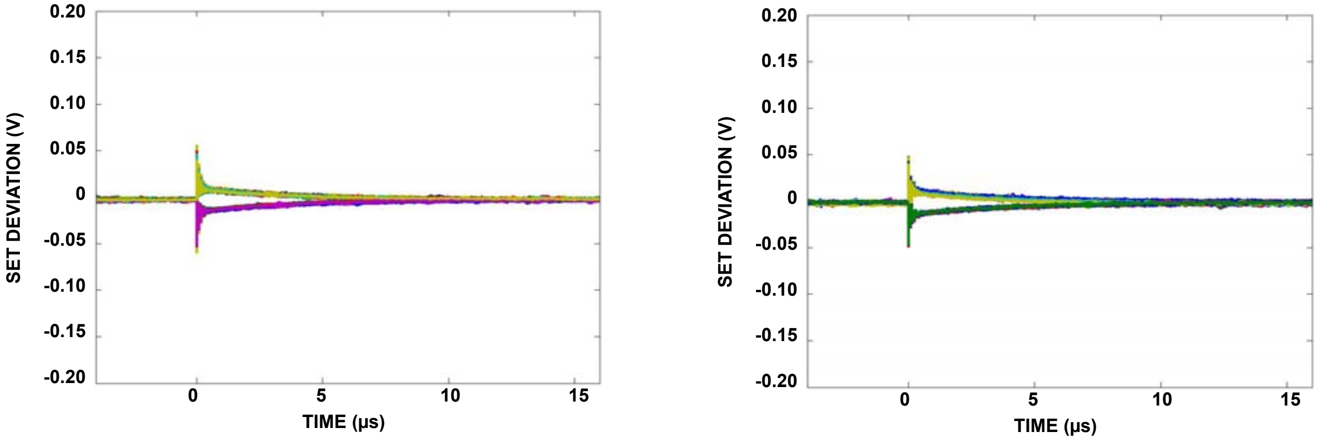


FIGURE 4C. DUT3, RUN 303

FIGURE 4D. DUT4, RUN 303

FIGURE 4. Figures 4A through 4D are composite plots of extreme SET for LET = 43MeV•cm^2/mg for DUT1 through DUT4 in Test 1, ±10.8V supplies. Each run was to a fluence of 4.0x10^6 ions/cm^2. Post processing selected the 20 largest and longest SET in both positive and negative deviations; not all of 80 such plots were unique. The oscilloscope setting limited the deviation range to ±0.2V

Composite Plots (Continued)

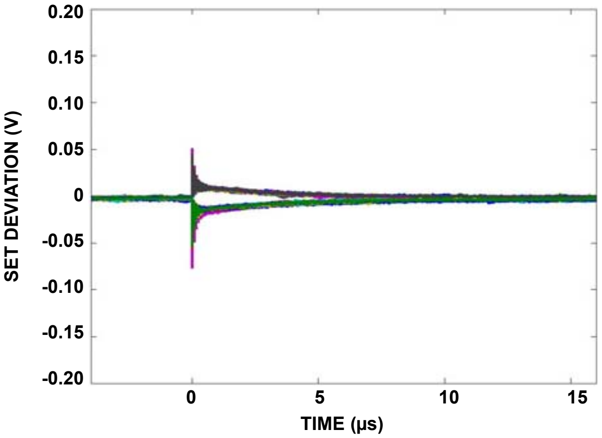


FIGURE 5A. DUT1, RUN 302

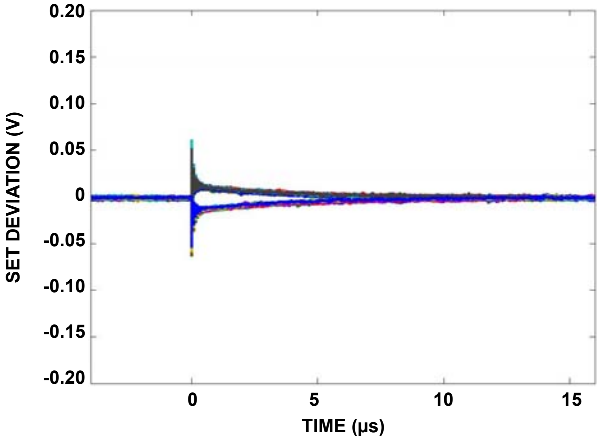


FIGURE 5B. DUT2, RUN 302

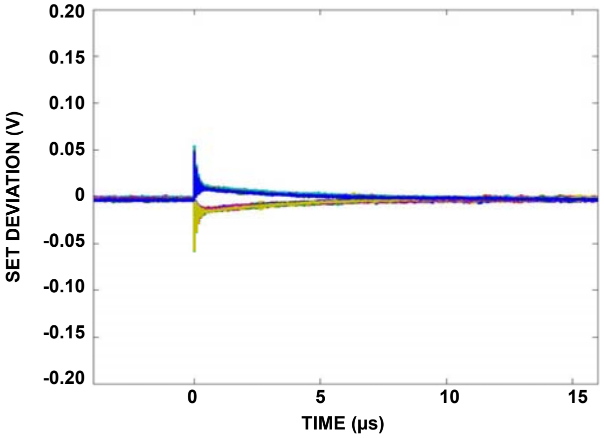


FIGURE 5C. DUT3, RUN 304

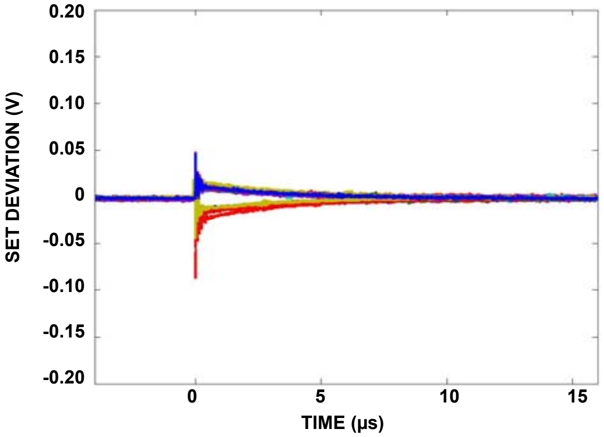
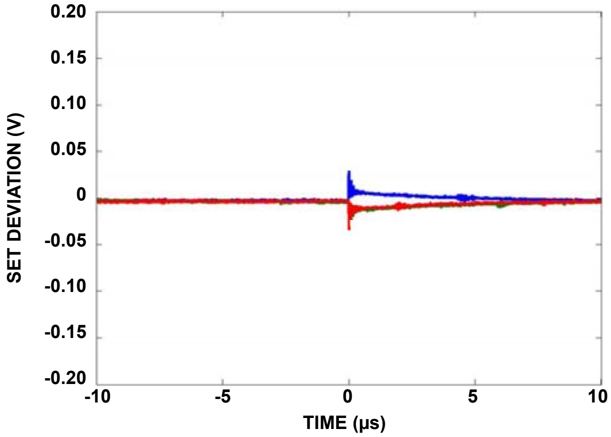


FIGURE 5D. DUT4, RUN 304

FIGURE 5. Figures 5A through 5D are composite plots of extreme SET for LET = 43MeV•cm^2/mg for DUT1 through DUT4 in Test 2, ±16.5V supplies. Each run was to a fluence of 4.0x10^6 ions/cm^2. Post processing selected the 20 largest and longest SET in both positive and negative deviations; not all of 80 such plots were unique. The oscilloscope setting limited the deviation range to ±0.2V.

Composite Plots (Continued)



No SET captured for DUT2 at ±10.8V

FIGURE 6A. DUT1, RUN 201

FIGURE 6B. DUT2, RUN 201

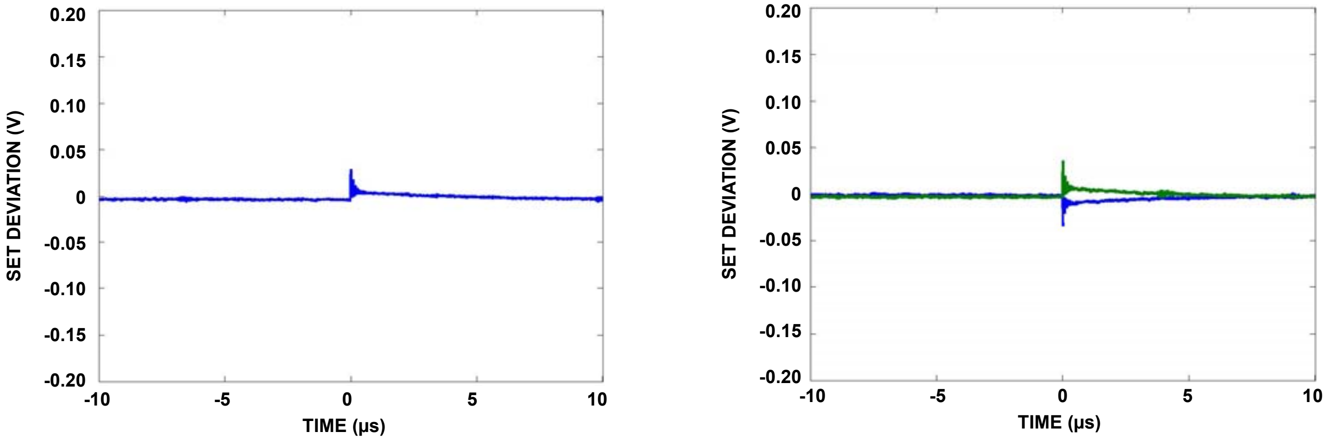


FIGURE 6C. DUT3, RUN 202

FIGURE 6D. DUT4, RUN 202

FIGURE 6. Figures 6A through 6D are composite plots of extreme SET for LET = 20MeV•cm^2/mg for DUT1 and DUT2. Test 1 with ±10.8V supplies is top row and Test 2 with ±16.5V supplies is bottom. Each run was to a fluence of 4.0x10^6 ions/cm^2. All captured SETs are plotted. The oscilloscope setting limited the deviation range to ±0.2V.

Figures 4A through 5D display the composite SET plots for the cases of LET = 43MeV•cm^2/mg. Clearly the SET deviations are of considerably lesser magnitude than for the case of LET = 86MeV•cm^2/mg and presage the results for captures at ±20mV for the case of LET = 20MeV•cm^2/mg.

Figures 6A through 6D represent all of the SET captured at LET = 20MeV•cm^2/mg triggering on ±20mV. The low counts encountered for the first four runs (DUT1 and DUT2 at ±10.8V and ±16.5V) led to the second pair of devices (DUT3 and DUT4) being skipped. The total of six SET captured and displayed in Figures 6A through 6D are equally distributed positive and negative and all have approximate magnitudes of just over the ±20mV needed for triggering.

Discussion and Conclusions

SEL and SEB

Testing with Au at LET∠0° = 86MeV•cm^2/mg did not result in any indications of SEB or SEGR at applied voltages up to the absolute maximum rating of ±20V for supplies and ±35V for inputs. The 2.954GeV Au had a range into silicon of 117µm and a Bragg Range of 53µm putting the Bragg peak well into the inactive handle wafer of the SOI part. Functionality and operational currents monitored did not change as a result of the irradiations carried out at a case temperature of +125°C. A minimal interpretation of the possible SEB/SEGR cross section is less than 1.5x10^{-7}cm^2 to a 95% confidence at LET = 86.4MeV•cm^2/mg at incidence of 0° for each of the input voltage conditions (±17V and ±35V). In the total testing, the SEB/SEGR possible cross section is less than 7.5x10^{-8} cm^2 at 95% confidence. Therefore, under normal operating conditions, the ISL71840SEH is not susceptible to SEB or SEGR failures up to normal incidence of LET = 86MeV•cm^2/mg.

SET Results

In SET testing, no indication of an addressing upset was noted. However, SET testing did result in events exceeding the ±20mV threshold criteria at all LET values tested (86, 43, and 20 MeV•cm^2/mg all at normal incidence). The SET events nearly vanished at an LET = 20MeV•cm^2/mg, yielding a nominal cross section of 3.75x10^{-7}, about 50x smaller than at 43MeV•cm^2/mg. However, this probably means that many SET were smaller than the trigger value of ±20mV, not that SET ceased to occur. The total cross section indicated by the SET capture counts topped out at 3.58x10^{-4} cm^2 at LET = 86MeV•cm^2/mg. The number of SET captures also depends upon the supply voltages with ±10.8V yielding slightly fewer captured SET than with ±16.5V, so that it appears the SET results from instantaneous coupling of the output to one of the supply rails. With a single exception, all the SET captured were within ±100mV deviation. The one exception was at -600mV peak and -200mV of output charging at LET = 86MeV•cm^2/mg.

The observed output SET had decay times of about 15µs. This is likely set by the capacitive loading on V_{OUT} (about 700pF from the cabling) and the resistance setting the nominal voltage (5kΩ). Thus, the predicted 3.5µs time constant is consistent with that observed. This is important since the application will determine this decay constant and hence the SET duration.

The SET study described here utilized a nominal V_{OUT} of 0.5V, very near GND, so that the rails were almost equally far from the nominal output voltage. It should be expected that, as the nominal V_{OUT} moves toward a supply rail, the SET toward that rail voltage would diminish in magnitude while those toward the opposite rail would increase in magnitude. Thus, the worst case SET for a nominal output near a supply rail could be two times the magnitudes recorded here.

The results presented above apply to both the ISL71840SEH and ISL73840SEH parts.

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