TEST REPORT

ISL72814SEH, ISL73814SEH

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 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 ISL72814SEH product. Although this report was written for the ISL72814SEH, it applies equally to the ISL73814SEH, which is the same silicon die and differs only in the total ionizing dose assurance testing.

Product Description

The ISL72814SEH is a radiation hardened, high-voltage, high-current switch array fabricated using Renesas' proprietary complementary bipolar PR40 Silicon-on-Insulator (SOI) process. The device integrates 16 switches that feature greater than a 42V breakdown voltage. The maximum DC current rating for each switch is 700mA.

To reduce solution size and increase system density, the ISL72814SEH integrates a 4-bit to 16-line decoder (plus enable pin). This conveniently selects 1 of the 16 available switch channels that provide switching from a positive supply to a common ground. The inputs to the decoder are four TTL/CMOS compatible address lines and one enable line.

The ISL72814SEH operates across the military temperature range from -55°C to +125°C and is available in a 28 Ld hermetic ceramic flat pack (CDFP) package.

The ISL72814SEH samples tested for this report were from the innovative lot XCP2E, wafer 09. 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.

Related Literature

For a full list of related documents, visit our website:

- ISL72814SEH, ISL73814SEH device pages

1. Test Description

1.1 Test Objective

The testing was intended to find the limits of the V_{CC} supply and channel voltages for avoiding destructive single event effects (such as SEB) at a Linear Energy Transfer (LET) of 86MeV·cm^2/mg (gold). Because of the SOI process, the part is inherently immune to single event latch-up (SEL). In addition, testing was carried out to look for significant single event transients (SET) impacting the switch channel activity at LET of 86MeV·cm^2/mg (gold), 28MeV·cm^2/mg (krypton), and 20MeV·cm^2/mg (copper).

1.2 Test Facility

Single event effects 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 which is capable of supplying a wide range of ion species and flux. The testing referred to here was done on June 19 to 20, 2018.

1.3 Test Set-Up

The schematic for SEE testing is shown Figure 1. The address lines were all grounded so that only CH0 was selectable using the EN pin. The OFF channels CH2 through CH15 were all wired in parallel to terminal CHX which was tied through a 100Ω resistor to VCOM (COM). The OFF channel CH1 was brought out separately to allow monitoring of a single OFF channel.

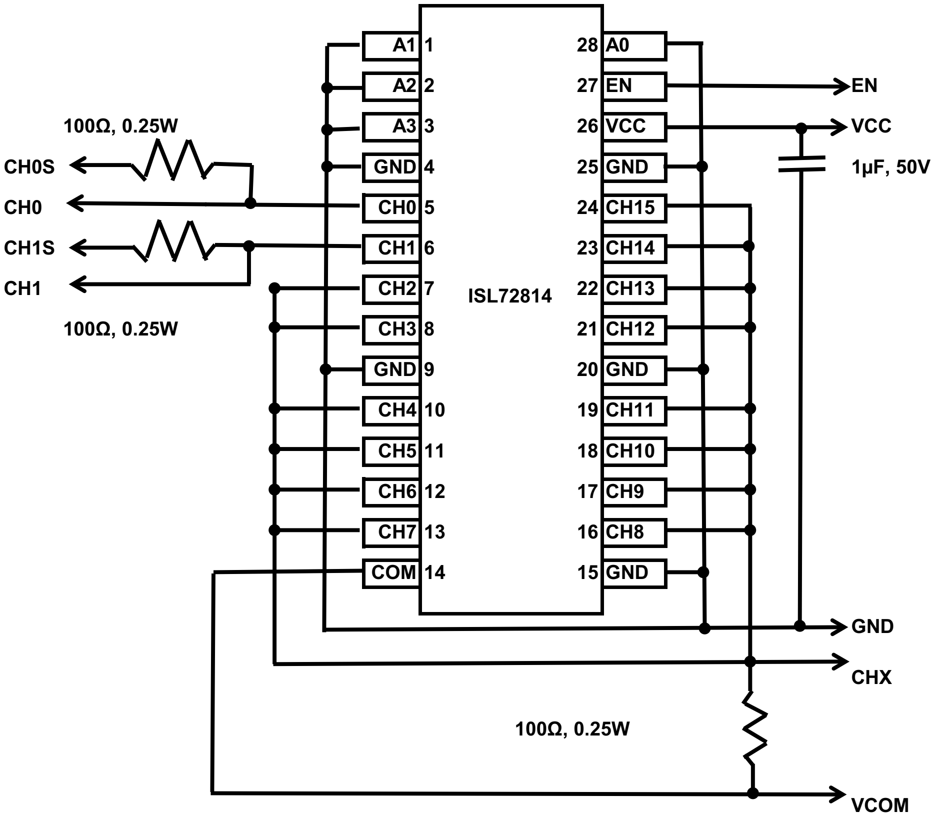

Figure 1. Schematic of the SEE testing arrangement for the ISL72814SEH.

For damaging single events (such as SEB) five parameters were measured before and after irradiation to look for changes indicative of damage. The logic supply current, I_{CC}, was measured at V_{CC} = 15V for both enabled

(EN = 15V) and disabled (EN = GND) conditions. The CH0 voltage (measured on CH0S) was measured while CH0 was enabled and forced to 700mA. Finally the CHX current was measured at CHX = 30V for both enabled and disabled states. For the damaging SEE testing thin film heaters were used on the back of the PCB to raise the case temperature of the part to 125°C ±10°C. Failures were determined at 10% changes across irradiation in enabled I_{CC} and for the CH0 voltage. The other leakage current parameters were considered failures at a 50% change across irradiation.

For the damaging single events (such as SEB) irradiations the V_{CC} supply and EN line were supplied with 15V. A current of 700mA was forced into the addressed CH0. The OFF channel voltages (CH1, CHX) were set to the test voltage in the range of 32V to 42V. The VCOM terminal was left open. The SEB irradiations tested were with normal incidence gold for LET of 86MeV·cm^2/mg to a fluence of 1x10^{7}ion/cm^2 at a flux of approximately 5x10^{4}ion/(cm^2·s).

For SET testing of the disabled part (EN = GND), the logic supply, V_{CC}, was tested at 3V and 4.5V to operate the digital logic with the least noise margin. The OFF channel biasing terminals (VCOM, CH0S, and CH1S) were supplied with 34V. All the OFF channels (CH0, CH1, and CHX) were monitored using oscilloscopes set to capture and store events. The oscilloscope triggers were set to ±2V around the nominal 34V so that any event that turned a channel ON to conduct more than 20mA would result in an event capture.

For single event transient (SET) testing of the enabled part (EN = V_{CC}), the logic supply, V_{CC}, was again tested at 3V and 4.5V. The OFF channels (VCOM and CH1S) were again supplied with 34V. The ON channel, CH0, was forced to carry 500mA. All the OFF channels (CH1 and CHX) were monitored using oscilloscopes set to capture and store events at ±2V transients. The ON channel, CH0, was monitored (CH0S) for the switch voltage and the oscilloscope trigger was set to ±20mV so that any event that changed the 500mA conduction voltage by more than 20mV was captured.

2. Test Results

2.1 SEB Testing Results at 86M•cm^2/mg

Damaging SEE testing started by testing a part (DUT1) at channel voltages starting at 32V and proceeding in 2V increments until failure or 42V. Subsequent parts were tested starting at 1V below the last passing voltage for DUT1 and proceeding with 1V increments until failure. The results of this testing are presented in Table 1. Failures, shown in bold, are determined by a 10% change in either enabled I_{CC} or the CH0 voltage at 700mA, or they were determined by a 50% change in either the disabled I_{CC}, the enabled CHX leakage, or the disabled CHX leakage.

Table 1. SEB testing results with LET = 86MeV•cm^2/mg, 125°C case temperature, and V_{CC} = 15V. Channel CH0 was conducting 700mA during irradiation. Tests indicating failures are in bold.

DUT	VCH	I_{CC} Enabled (mA) 10%		I_{CC} Disabled (µA) 50%		VCH0 700mA (V) 10%		ICHX at 30V Enabled (µA) 50%		ICHX at 30V Disabled (µA) 50%	
		Pre	Delta	Pre	Delta	Pre	Delta	Pre	Delta	Pre	Delta
1	40	6.5	0%	405	-2%	1.226	0%	0.502	12%	0.215	14%
	42	6.5	0%	396	3%	1.228	0%	0.564	11%	0.245	18%
2	43	6.7	0%	575	0%	1.228	0%	0.168	23%	0.085	12%
	44	6.7	0%	577	-2%	1.230	0%	0.206	**>5mA**	0.095	**>5mA**
3	42	6.5	0%	392	5%	1.217	0%	0.288	**>5mA**	0.151	**>5mA**
4	38	6.9	0%	586	-5%	1.221	0%	0.082	**>5mA**	0.059	**>5mA**
5	37	6.5	0%	411	0%	1.214	1%	0.382	6%	0.189	23%
	38	6.5	0%	413	0%	1.223	0%	0.404	**62%**	0.232	**77%**
6	35	6.7	0%	563	2%	1.225	0%	0.125	**>5mA**	0.089	**>5mA**
7	35	6.3	0%	399	-4%	1.221	0%	0.33	24%	0.19	21%
	36	6.3	0%	385	4%	1.224	0%	0.409	**>5mA**	0.23	**>5mA**

Of the six failing parts, the voltages at failure ranged from 35V to 44V. The lowest fail, DUT6 at 35V, was at the first voltage tested on that particular DUT. However, four DUTs (DUT1, DUT2, DUT5, and DUT7) were tested at 35V or greater without failure. The SEB testing results support the conclusion that the ISL72814SEH, biased at V_{CC} = 15V and OFF channels at 34V, is immune to damaging SEE for irradiation with normal incidence LET=86MeV·cm^2/mg ions with a case temperature of 125°C ±10°C.

2.2 Testing Results for SET

SET testing consisted of running four unique parts at each of the three LET levels (86, 28, and 20MeV·cm^2/mg) for a total of twelve parts. Each part was tested at four operating conditions bringing the number of irradiation runs to 48. First, the part was disabled (all channels OFF) and tested at V_{CC} = 3.0V and 4.5V. Next, the part was enabled (addressing CH0) and tested again at the two V_{CC} levels.

Throughout the SET testing channels CH2 through CH15 were OFF. All 14 of these OFF channels were wired in parallel as CHX with a 100Ω resistor to VCOM which was biased at 34V. An SET resulting in conduction of any of these 14 channels led to a voltage transient on CHX. The transients were captured and stored by an oscilloscope set to trigger on a 2V transient (20mA). The oscilloscope also captured the voltages on CH1 and CH0 at the same time.

CH1 was also OFF for all SET testing and was biased through a 100Ω resistor to 34V and CH1 was monitored with another oscilloscope using a 2V trigger on the channel to capture and store the events. Again the other two voltages, CH0 and CHX, were also captured by the oscilloscope at the same time.

Finally, CH0 was monitored for SET. In the case where the part was disabled (EN = GND), CH0 was OFF, and it was biased and monitored in a fashion similar to CH1 described above. When the part was enabled (EN = V_{CC}), CH0 was ON and had 500mA forced through it. In this case, the voltage CH0S was monitored and captured by an oscilloscope set to trigger at a 20mV deviation from its nominal value. The voltages on CH1 and CHX were also captured by the oscilloscope at the same time.

Review of the SET captures for CHX at 86MeV·cm^2/mg revealed that many triggering events were very short spikes of much less than the 34V bias. Investigation indicated that noise coupling between channels led to triggering such that events were not always originating on the signal monitored for triggering. An example of this situation is represented in Figure 2 on page 5. In this case the triggering was on the CHX (red) signal. However, the waveforms for CH1 were searched for the ten longest events with at least a 30V deviation. Although the ten events in Figure 2 obviously originated on CH1, CHX saw enough disturbance to trigger capture of the events.

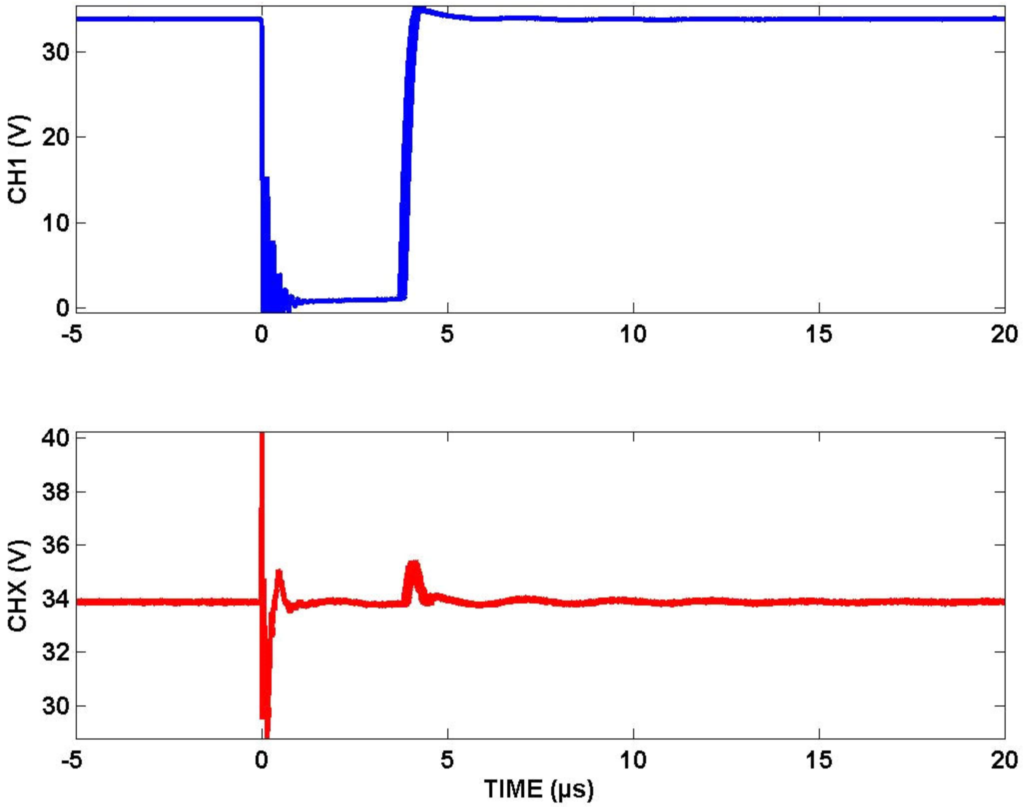

Figure 2. Composite of the ten longest CH1 transients for disabled DUT8 at V_{CC} = 3.0V with 86MeV•cm^2/mg. Triggering was done on CHX (red) with CH1 (blue) concurrently captured.

This noise coupling worked in the reverse direction where an event on CHX would register noise coupling onto CH0 and CH1. In this direction, the more frequent events on CHX (14 channels combined) produced a much higher proportion of noise events on the CH0 and CH1 triggered capture records, greatly complicating the analysis of the CH0 and CH1 data.

In addition to the noise coupling, many short and shallow events were also captured. In an effort to focus attention on the larger and longer SET, the collection of SET captures were filtered to select only those SET that exceeded a 30V deviation (300mA) for more than 1µs. This filtering selected approximately 17,000 SET out of the raw 86,000 count, or about one out of five. These limits were arbitrary but provided a data set that highlighted the larger and longer SET that were seen. The change in V_{CC} voltage did not appreciably impact the SET populations of the filtered CHX data so the SET data for the two voltages were merged: The results are presented on a type of probability plot in Figure 3 on page 6.

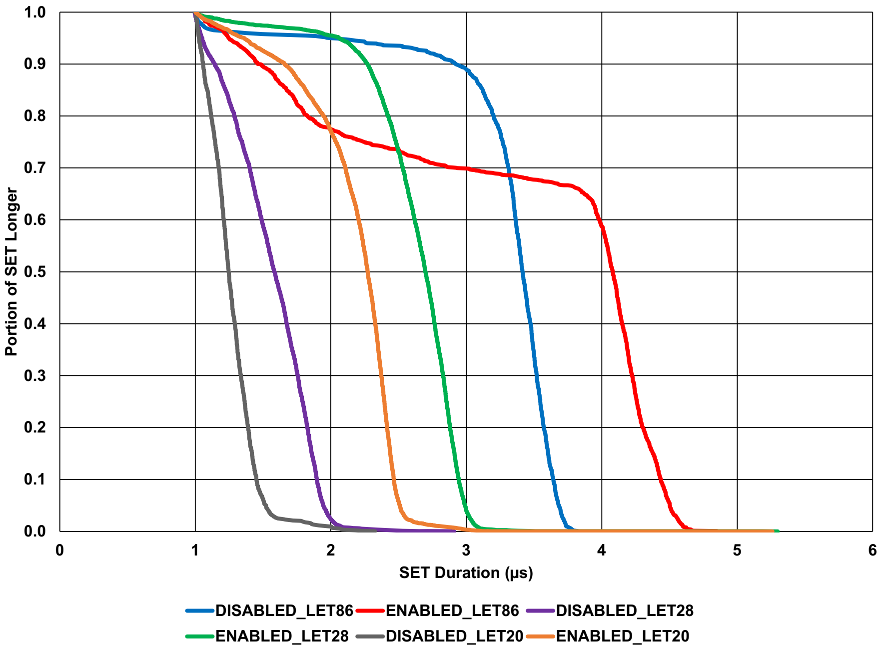

Figure 3. Probability plot of the CHX SET data filtered for greater than 1µs at a deviation of greater than 30V (300mA through the 100Ω) out of the 34V bias.

Each of the plotted data sets in Figure 3 is the combination of four parts (unique for each LET), each tested at the two V_{CC} voltages for a total of eight irradiation runs. For the 86MeV·cm^2/mg cases the plot data represents a total fluence of 8.0x10^{6}ion/cm^2 per plot line, while for the two lower LET each plot line represents 1.6x10^{7}ion/cm^2. The ultimate SET durations (beyond the 1µs filter limit) show marked dependence on radiation LET. This is an expected result as the energy delivered by the ion is reflected in the length of the SET. However, an unexpected result was that the state of the enable on the part also had a significant impact on the duration of the SET. The enabled state produced longer SET than the disabled state. The longest SET captured was 5.3µs for an enabled part at 28MeV·cm^2/mg. Inspection of the three longest SET identified them as double events, which explained their rarity.

Cross sections for OFF channel SET based on the results of the single channel CH1 data are summarized in Table 2. The data represents a wide range of cross sections going from a maximum of 4400µm^2 for 86MeV·cm^2/mg down to a minimum of 500µm^2 for 20MeV·cm^2/mg. The SET were still relatively common even at 20MeV·cm^2/mg indicating that an LET threshold for these SET must be at a substantially lower LET.

Table 2. CH1 SET cross sections for events that exceeded 30V deviation (>300mA) and 1µs duration on parts biased at 34V. The results for four parts at each condition were combined to yield the mean, minimum, and maximum cross sections for those parts.

		30V Deviation and 1µs Duration SET Cross Sections (µm^2)					
LET (MeV·cm^2/mg)	V_{CC} (V)	CH1 OFF and Disabled			CH1 OFF and Enabled		
		MEAN	MIN	MAX	MEAN	MIN	MAX
86	3.0	2300	1600	3000	4075	3600	4400
	4.5	2000	1400	2600	2950	1700	3800
28	3.0	1800	1050	2450	3025	2750	3500
	4.5	2063	1850	2550	2163	1800	2500
20	3.0	1075	1000	1250	1913	500	3100
	4.5	1088	850	1300	2300	1750	2550

It was noted earlier that the events on CH1 and CHX seem to be relatively independent with transient edge coupling between the channels. Although that is mostly true, there are some SET that appear to be common to both CH1 and CHX. An example of these common SET is presented in Figure 4 for CH1 and CHX transients that concurrently exhibit deviations of 30V or more. The strong similarity of the seven plotted SET implies a common cause. Such a common cause is likely the transient ESD clamp on the COM node which discharges all the switch channels together if it is tripped. In the sixteen runs at 86MeV·cm^2/mg, the average cross section for the events was 200µm^2 with a maximum of 700µm^2 (for an enabled part). At 28MeV·cm^2/mg, there were no coincident CH1 and CHX 30V events in sixteen runs at 2.0x10^{6}ion/cm^2 for each run.

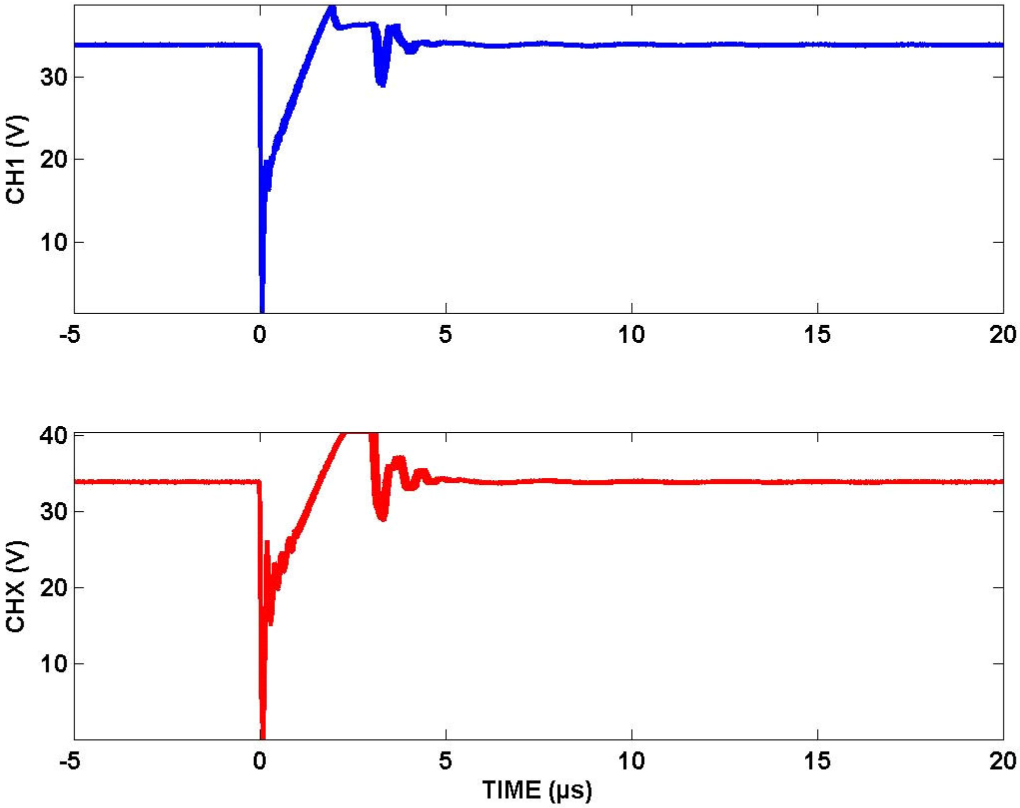

Figure 4. Composite plot of CH1 (coincidental) and CHX (triggered at 2V) SET where both exceeded 30V deviation on the same capture. This plot is the seven events captured on DUT9 for 86MeV•cm^2/mg irradiation.

Examination of the captures for the 20mV trigger of the ON channel CH0 revealed that the vast majority of captures were transients of less than 100mV excursion and less than 1µs duration. In fact, most SET appeared to be noise coupling from events occurring on the OFF channels. Consequently, the 20mV triggered CH0 events were filtered to select those events that were greater than +100mV deviation from initial value for more than 1µs. The post processing was applied to the captured data.

A composite plot of the filtered ON channel events from the run of DUT19 at V_{CC} = 3.0V and 20MeV·cm^2/mg is presented in Figure 5 on page 8. There are a total of fourteen transients in the plot. All of them have essentially identical beginnings, starting at about 1.07V (the saturation value of the switch with 500mA), then rising to the clipping level of the oscilloscope input at about 1.27V. The rise in voltage indicates the switch is no longer in full conduction and has begun to switch OFF. The current supply providing the 500mA pushes the voltage up toward a 20V compliance level although that is not captured by the oscilloscope. After a period of time from 25µs to 35µs above the 1.27V clipping level, the switch turns ON again and the voltage spikes low to about 0.9V. After the spike, the voltage goes through a recovery transient that includes an overshoot and decay back to the 1.07V switch voltage for 500mA. The recovery transient can hit the oscilloscope clipping level again as seen for the longer transients. The full recovery transients are not captured in the 45µs span of the capture. The post processing program was tailored to ignore the rebound of the recovery and only measure the event from the trigger (+20mV) to the spike down.

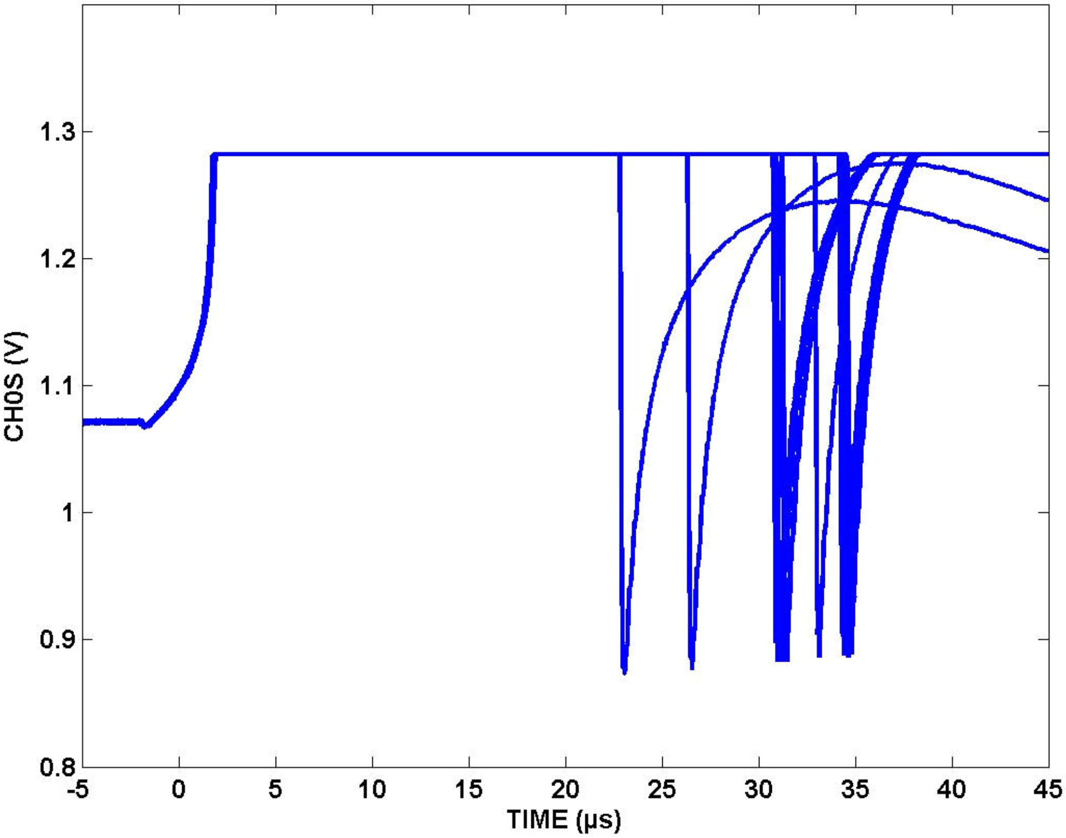

Figure 5. Composite of the 14 ON CH0 transients that exceeded 100mV for more than 1µs for DUT19 run at 20MeV•cm^2/mg with V_{CC} = 3.0V.

The filtered ON CH0 resulted in a total of 578 CH0 ON events to the +100mV deviation and greater than 1µs duration logged for all of the SET testing. The SET counts per irradiation run were widely disparate with a minimum of 1 event in 1.0x10^{6}ion/cm^2 (for DUT8 and DUT10 at V_{CC} = 4.5V with 86MeV·cm^2/mg) and a maximum of 98 in 2.0x10^{6}ion/cm^2 (for DUT14 at V_{CC} = 3.0 with 28MeV·cm^2/mg). The minimum cross section was then 100µm^2, and the maximum cross section was 4900µm^2. The lengths of the SET were slightly dependent on LET. At 86MeV·cm^2/mg the maximum SET duration (beyond 100mV deviation) was 39.2µs, while at 20MeV·cm^2/mg the maximum duration was 34.5µs.

3. Discussion and Conclusions

Single Event Burnout (SEB) testing supports the conclusion that the ISL72814SEH can survive environments with normal incidence 86MeV·cm^2/mg ions to 1x10^{7}ion/cm^2 at biases of V_{CC} = 15V and switch blocking of 34V while at 125°C ±10°C case temperature. There was some variability in the failure voltage, from 35V up to 44V. The lowest failure recorded was 35V. Four units passed SEB testing at 34V or greater, while one unit failed at 35V without being tested at a lower voltage.

Single Event Transient (SET) testing revealed OFF channel conduction events up to 340mA (34V across the 100Ω resistor). SET of at least 1µs duration beyond a 30V deviation (300mA) registered a maximum duration of 5.3µs and maximum cross section of 4400µm^2 at 86MeV·cm^2/mg. At 20MeV·cm^2/mg, the maximum cross section recorded was 3100µm^2. No threshold LET was established for the OFF channel conduction events of 1µs and 30V (300mA) deviation.

SETs occurring for an ON channel (CH0) cause loss of switch conduction for the duration of such transients. The transients were defined as more than 1µs duration at a 500mA conduction voltage of +100mV deviation above the switch nominal saturation voltage at the current. Transients up to 39µs long were recorded in the SET testing for 86MeV·cm^2/mg. No ON channel threshold LET was established as the events occurred down to 20MeV·cm^2/mg. The events recorded a maximum cross section of 4900µm^2 at 28MeV·cm^2/mg.

The SET disturbances on the channels lasting tens of microseconds make the use of the ISL72814SEH for fast response loads contraindicated. However, with the SET durations limited to 40µs or less, slow response inductive loads such as relays should not be adversely impacted by the SET.

4. Revision History

Rev.	Date	Description
1.00	Jan 8, 2019	Initial release

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