ISL71091SEHxx Family

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 in electronic circuitry, including Single Event Upset (SEU), Single Event Transient (SET), Single Event Functional Interrupt (SEFI), 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 ISL71091SEHxx product family or precision references design for space applications.

Product Description

The ISL71091SEHxx is a family of ultra low noise, high DC accuracy precision voltage reference products with an input range to 30V. Four output voltage variants are available, 3.30V (ISL71091SEH33), 2.048V (ISL71091SEH20), 4.096V (ISL71091SEH40), and 10.0V (ISL71091SEH10). The ISL71091SEHxx use the Intersil PR40 Advanced Bipolar technology to achieve sub 4µV_{P-P} noise at 0.1Hz and achieve 0.25% accuracy over radiation. Its implementation in an advanced bonded wafer SOI process using deep trench isolation results in fully isolated structures and latch-up free performance, whether electrically or single event (SEL) caused.

Product Documentation

For more information about the ISL71091SEHxx, refer to the following documentation.

- ISL71091SEHxx datasheets:
  - ISL71091SEH33 (3.300V)
  - ISL71091SEH20 (2.048V)
  - ISL71091SEH40 (4.096V)
  - ISL71091SEH10 (10.00V)
- Standard Microcircuit Drawing (SMD): 5962-14208
- ISL71091SEHxx Application Note:
  - AN1906 “ISL71091SEHXXEV1Z User’s Guide”

SEE Test Objectives

The ISL71091SEHxx was tested to determine its susceptibility to Single Event Burnout (SEB, destructive ion effects) and to characterize its Single Event Transient (SET) behavior over various Linear Energy Transfer (LET) levels.

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.

SEE Test Set-up

SEE testing is carried out with the sample in an active configuration. A schematic of the ISL71091SEHxx SEE test fixture is shown in Figure 1. The test circuit is configured to accept an input voltage from 4V to 30V and generate the nominal output voltage. The output current of the reference was adjusted using fixed load resistors on a test board.

Four ISL71091SEHxx test fixtures were mounted to a test jig, which could be moved with respect to the ion beam. The parts were assembled in dual in-line packages with the metal lid removed for beam exposure. Using 20-foot coaxial cables, the test jig was connected to a switch box in the control room, which contained all of the monitoring equipment. The switch box allowed any one of the four test circuits to be controlled and monitored remotely.

In later testing a single board with four devices mounted so that all four could be exposed to the ion beam at once. This allowed testing of four parts simultaneously.

Digital multimeters were used to monitor input voltage (V_{IN}), output voltage (V_{OUT}) and input current (I_{IN}). LeCroy *wave*Runner 4-channel digital oscilloscopes were used to capture and store SET traces at V_{OUT} that exceeded the oscilloscope trigger level.

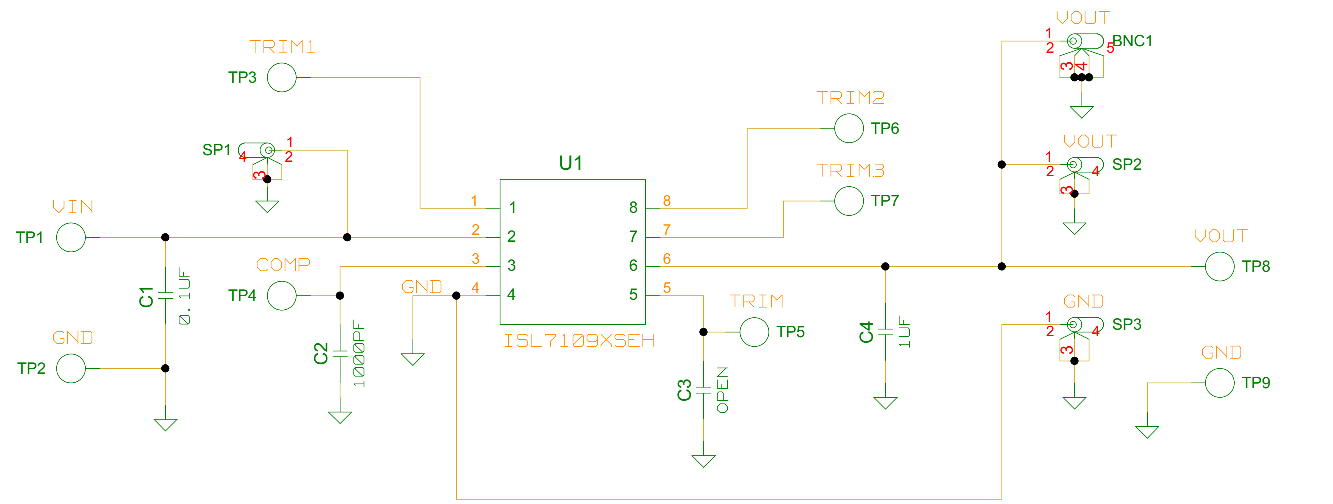

FIGURE 1. SCHEMATIC OF THE ISL71091SEHXX SEE TEST CIRCUIT

NOTE:

1. The output capacitor (C_{OUT}), C_4, was varied between 0.1µF and 10µF and the compensation capacitor (C_{COMP}), C_2, was varied between 1nF and 10nF.

SEB Testing of ISL71091SEH33 (3.3V) Reference

For the SEB tests, conditions were selected to maximize the electrical and thermal stresses on the Device Under Test (DUT), thus insuring worst-case conditions. The input voltage (V_{IN}) was initially set to 35V, and then increased in 1V increments. SEB testing was conducted with the ISL71091SEH33, hence the output voltage (V_{OUT}) was 3.3V. Output current (I_{OUT}) was set to either 5mA (sinking current) or 10mA (sourcing current), which are the limits of load regulation current for the parts. The output capacitance was tested at both 0.1µF and 10µF. Case temperature was maintained at +125°C by controlling the current flowing into a resistive heater bonded to the underside of the DUT. This insured that the junction temperature of the DUT exceeded +125°C, which is the maximum junction temperature anticipated for high reliability applications. Four devices were irradiated with Au ions at a normal incident angle, resulting in an effective LET of 86.4 MeV • cm^2/mg. Table 1 summarizes the results of SEB testing. The chart shows sample size and passing results for an input voltage level of 36V on each device.

From a silicon design perspective all the products in the ISL71091SEHxx product family are exactly the same in silicon. The output voltages are produced by the same circuitry and trimmed through a resistor ladder network. Therefore, the ISL71091SEH33 SEB results are applicable to the complete product family of ISL71091SEHxx parts.

TABLE 1. ISL71091SEH33 SEB TEST RESULTS

TEST ID	DEVICE #	V_{IN}	V_{OUT} PRE	V_{OUT} POST	V_{OUT} DELTA (%)	I_{OUT} (A)	C_{OUT} (µF)	PRE SEE I_{IN} (mA)	POST SEE I_{IN} (mA)	DELTA I_{IN} (%)
401	1	35	3.3284	3.3286	0.01%	-0.005	0.1	0.3312	0.3311	-0.03
	2	35	3.3004	3.3003	0.00%	0.01	0.1	10.593	10.591	-0.02
	3	35	3.3022	3.3016	-0.02%	0.01	10	10.539	10.535	-0.04
	4	35	3.3252	3.3249	-0.01%	-0.005	10	0.3274	0.3246	-0.86
402	1	36	3.3286	3.3284	-0.01%	-0.005	0.1	0.3316	0.3316	0.00
	2	36	3.3003	3.3001	-0.01%	0.01	0.1	10.591	10.589	-0.02
	3	36	3.3016	3.3015	0.00%	0.01	10	10.535	10.534	-0.01
	4	36	3.3249	3.3248	0.00%	-0.005	10	0.3252	0.3236	-0.49
403	1	38	3.3284	4.3	29.19%	-0.005	0.1	0.3324	na	
	2	38	3.3001	0.0012	-99.96%	0.01	0.1	10.589	na	
	3	38	3.3015	3.3009	-0.02%	0.01	10	10.534	10.528	-0.06
	4	38	3.3248	4.0779	22.65%	-0.005	10	0.3245	na	

TABLE 1. ISL71091SEH33 SEB TEST RESULTS (Continued)

TEST ID	DEVICE #	V_{IN}	V_{OUT} PRE	V_{OUT} POST	V_{OUT} DELTA (%)	I_{OUT} (A)	C_{OUT} (µF)	PRE SEE I_{IN} (mA)	POST SEE I_{IN} (mA)	DELTA I_{IN} (%)

NOTE:

2. Samples were tested with increasing input voltage (V_{IN}) until failure as determined by more than 1% change in either V_{OUT} or I_{IN}. The chart shows passing results for the input voltage levels of 35V and 36V and failures at 38V. Each irradiation was to $5x10^6$ ions/cm^2 at a rate of $2.5x10^4$ ions/(cm^{2}s).

SET Testing of ISL71091SEH33, 3.3V Reference

The first SET testing of the ISL71091SEHxx family was done on four samples of the ISL71091SEH33. Two parts had C_{OUT} = 0.1µF and two parts had C_{OUT} = 10µF. Irradiation was done at room temperature with LET of 8.5, 28, and 60 MeV•cm^2/mg. Samples had V_{IN} varied over 5.5V to 16.5V. V_{IN} was limited to 16.5V due to the observed large SET at V_{IN} = 30V which still represented in Figure 3 at V_{IN} = 16.5V. Table 2 shows the SET summary giving the cross section for each input voltage and LET level. Figure 2 is the LET threshold plot representing Table 2.

TABLE 2. SET SUMMARY OF ISL71091SEH33 (3.3V) SAMPLES

LET	V_{IN}	I_{OUT} (mA)	C_{OUT} (µF)	SET COUNT	NET FLUENCE (p/cm^2)	CROSS SECTION (cm^2)
60	16.5	1	10	71	1.0E+07	7.1E-06
60	16.5	1	10	11	1.0E+07	1.1E-06
60	13.2	1	0.1	2661	1.0E+07	2.7E-04
60	13.2	1	0.1	2558	1.0E+07	2.6E-04
60	5.5	1	0.1	1806	1.0E+07	1.8E-04
43	16.5	1	0.1	1817	1.0E+07	1.8E-04
43	13.2	1	0.1	1629	1.0E+07	1.6E-04
43	5.5	1	0.1	1238	1.0E+07	1.2E-04
28	16.5	1	0.1	672	5.0E+06	1.3E-04
28	13.2	1	0.1	676	5.0E+06	1.4E-04
28	11	1	0.1	662	5.0E+06	1.3E-04
28	5.5	1	0.1	572	5.0E+06	1.1E-04
8.5	16.5	1	0.1	188	5.0E+06	3.8E-05
8.5	13.2	1	0.1	191	5.0E+06	3.8E-05
8.5	5.5	1	0.1	158	5.0E+06	3.2E-05

NOTE:

3. Trigger level for the output voltage was set to ±30mV and C_{COMP} = 1nF.

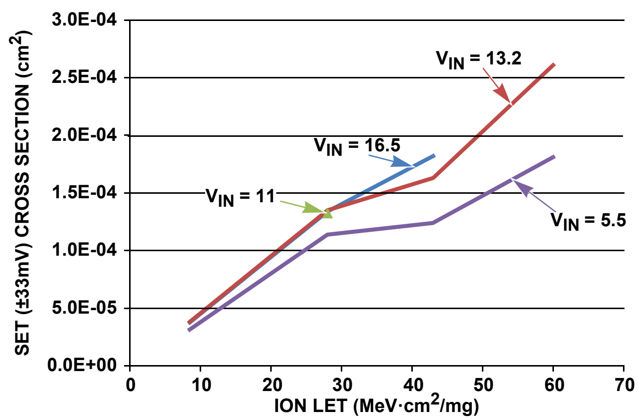

FIGURE 2. ISL71091SEH33 LET THRESHOLD PLOT FOR ±30mV TRIGGER WINDOW WITH C_{OUT} = 0.1µF AND I_{OUT} = 1mA.

The data presented above only counts SET that exceed ±30mV. Closer inspection of SET reveals that there is a significant spread in the size and duration of the SET included in those counts. Most notably, at higher V_{IN} and LET a set of very large and long SET appears. Figure 3 shows a sampling of these large SET for V_{IN} = 16.5V and LET = 60. The largest from this particular run was over +300mV from nominal and lasted well over 1ms.

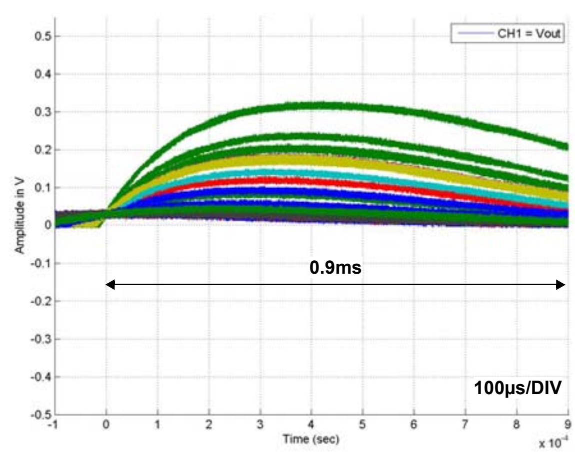

FIGURE 3. COMPOSITE (58) PLOT OF SELECTED LARGE AND LONG SET FOR ISL71091SEH33 AT LET = 60, V_{IN} = 16.5V, I_{OUT} = 1mA, C_{OUT} = 10µF

Lowering the input voltage to V_{IN} = 13.2V significantly suppressed the magnitude of the SET as can be noted in Figure 4. Thus the input voltage is a strong determiner of this large and long SET category.

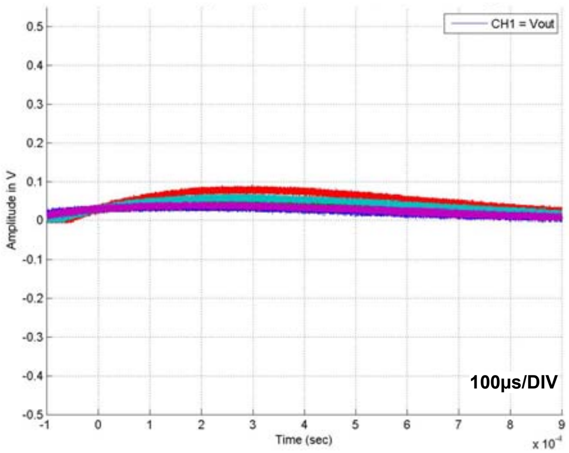

FIGURE 4. COMPOSITE (5) PLOT OF SELECTED LARGE AND LONG SET FOR ISL71091SEH33 AT LET = 60, V_{IN} = 13.2V, I_{OUT} = 1mA, C_{OUT} = 10µF

It is also worth noting that reducing the output capacitor from 10µF to 0.1µF is effective in shortening the SET disturbance but is not effective in reducing the magnitudes. Comparing the magnitudes of Figure 5 with those of Figure 3 illustrates this point. In both figures, the peak prolonged SET is about +300mV, while in Figure 3 it persists over 1ms whereas in Figure 5 the SET is limited to within 200µs. Figures 3 through 7 indicate a strong dependence of SET magnitude on V_{IN} and a strong dependence of the SET duration on C_{OUT}. Just as a confirmation, Figure 6 compared to Figure 3 demonstrates the impact of both V_{IN} and C_{OUT}, although the peak magnitudes roughly double those of Figure 4. Finally, Figure 7 shows that the large and long SET are gone with a V_{IN} = 5.5V at LET = 28. Only sharp spike SET remain (both positive and negative), with magnitudes larger than the slow events at C_{OUT} = 10µF.

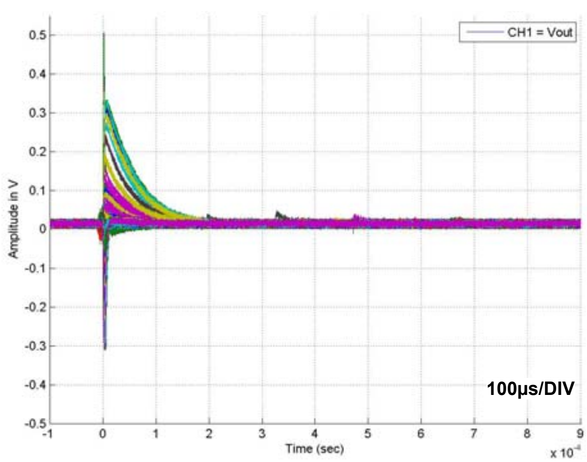

FIGURE 5. COMPOSITE (250) SET PLOT FOR ISL71091SEH33 AT LET = 60, V_{IN} = 16.5V, I_{OUT} = 1mA, C_{OUT} = 0.1µF

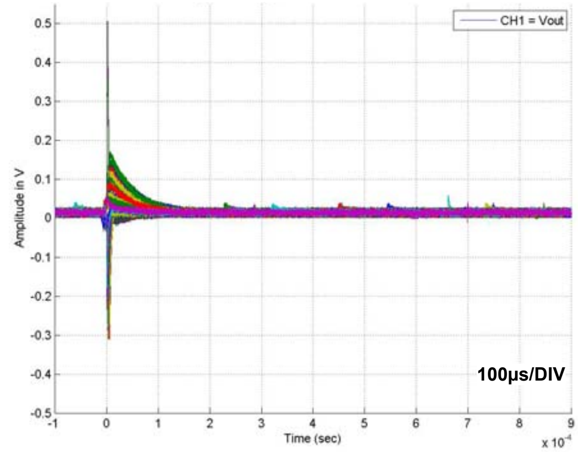

FIGURE 6. COMPOSITE (250) SET PLOT FOR ISL71091SEH33 AT LET = 60, V_{IN} = 13.2V, I_{OUT} = 1mA, C_{OUT} = 0.1µF

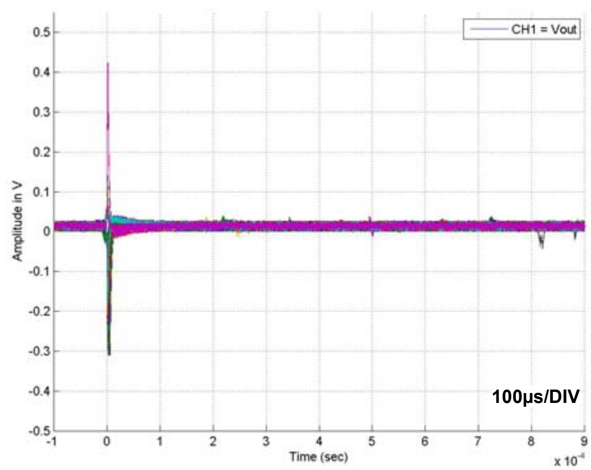

FIGURE 7. COMPOSITE (250) SET PLOT FOR ISL71091SEH33 AT LET = 28 V_{IN} = 5.5V, I_{OUT} = 1mA, C_{OUT} = 0.1µF, C_{COMP} = 1nF.

SET Testing of ISL71091SEH20, 2.048V Reference

Four of the ISL71091SEH20 2.048 references were run to test for SET. A summary of the conditions and the SET counts obtained is in Table 3.

TABLE 3. SET SUMMARY OF ISL71091SEH20 (2.048V) SAMPLES

LET	C_{OUT} (µF)	C_{COMP} (nF)	V_{IN}	PART A EVENTS (±20mV)	PART B EVENTS (±20mV)	NET CROSS SECTION (cm^2)
60	1.0	1	16.5	416	663	1.1E-04
60	0.1	1	16.5	1787	1273	3.1E-04
60	1.0	1	13.2	449	549	1.0E-04
60	0.1	1	13.2	1671	1310	3.0E-04
60	1.0	1	5.5	316	467	7.8E-05
60	0.1	1	5.5	1391	2988	4.4E-04
28	1.0	1	16.5	102	148	2.5E-05
28	0.1	1	16.5	707	665	1.4E-04
28	1.0	1	13.2	68	133	2.0E-05
28	0.1	1	13.2	633	622	1.3E-04
28	1.0	1	11	38	138	1.8E-05
28	0.1	1	11	665	583	1.2E-04
28	1.0	1	5.5	41	42	8.3E-06
28	0.1	1	5.5	634	567	1.2E-04
8.5	1.0	1	16.5	0	1	1.0E-07
8.5	0.1	1	16.5	181	151	3.3E-05
8.5	1.0	1	13.2	0	0	–
8.5	0.1	1	13.2	188	173	3.6E-05
8.5	1.0	1	5.5	2	1	3.0E-07
8.5	0.1	1	5.5	162	120	2.8E-05

NOTE:

4. Trigger level for the output voltage set to ±20mV and I_{OUT} = 1mA. Each irradiation was to $5x10^6$ ion/cm^2.

SET for the ISL71091SEH20 varied considerably with the selection of C_{OUT} (either 0.1µF or 1µF) and the headroom voltage on V_{IN}. Examples of the SET waveforms captured are shown in Figures 8 through 12.

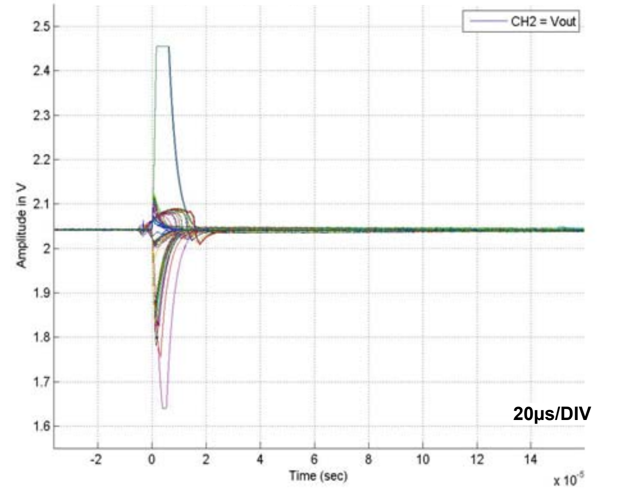

FIGURE 8. COMPOSITE (100) PLOT OF SET FOR ISL71091SEH20 AT LET = 60 V_{IN} = 16.5V, I_{OUT} = 1mA, C_{OUT} = 0.1µF, C_{COMP} = 1nF. TRIGGER AT ±20mV, WHILE SCOPE TRUNCATES SET TRACES AT ±400mV.

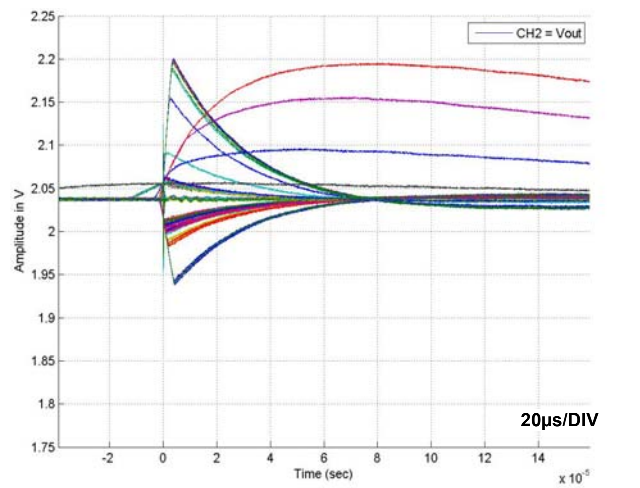

FIGURE 9. COMPOSITE PLOT OF 100 SET FOR ISL71091SEH20 AT LET = 60 V_{IN} = 16.5V, I_{OUT} = 1mA, C_{OUT} = 1µF, C_{COMP} = 1nF. TRIGGER AT ±20mV.

Figures 8 and 9 show the SET resulting with V_{IN} = 16.5V and LET = 60 MeV•cm^2/mg. In the case of Figure 8 (C_{OUT} = 0.1µF) some SET exceeded 400mV deviation from the 2.048V regulation point, both positive and negative at I_{OUT} = 1mA. In this case, the SET duration was about 30µs.

For Figure 9 (C_{OUT} = 1µF) the SET deviations were limited to about +250mV and -100mV at I_{OUT} = 1mA. However, the durations are much longer with some overshoot (undershoot) evident beyond 80µs. A few SET in Figure 9 are very long and extrapolate out to about 1ms, but this again is at V_{IN} = 16.5V. These events represent a cross section of about $2x10^{-6}$ cm^2. These very long SET are consistent with what was seen on the ISL71091SEH33 (3.3V) reference. It is interesting to note that these long SET disappeared with a reduced V_{IN} = 13.2V as exhibited in Figure 10. Figure 11 is also free of these long SET for V_{IN} = 5.5V, and a moderate reduction in SET peak deviations is also seen. LET = 28 MeV•cm^2/gm is insufficient to generate these long SET even with V_{IN} = 16.5V, as shown in Figure 12 as compared to Figure 9.

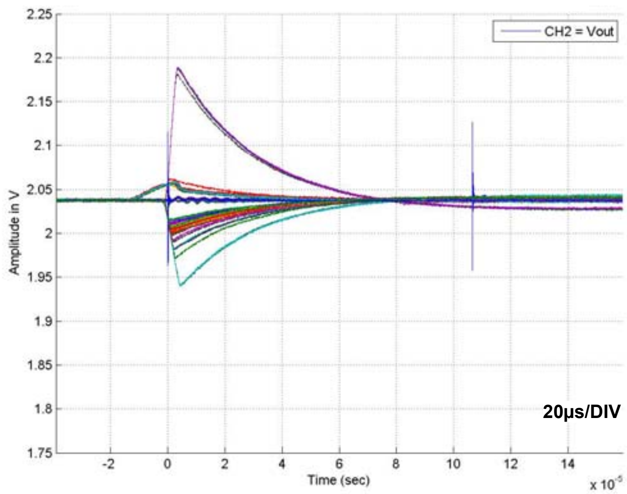

FIGURE 10. COMPOSITE (100) PLOT OF SET FOR ISL71091SEH20 AT LET = 60 V_{IN} = 13.2V, I_{OUT} = 1mA, C_{OUT} = 1µF, C_{COMP} = 1nF. TRIGGER AT ±20mV.

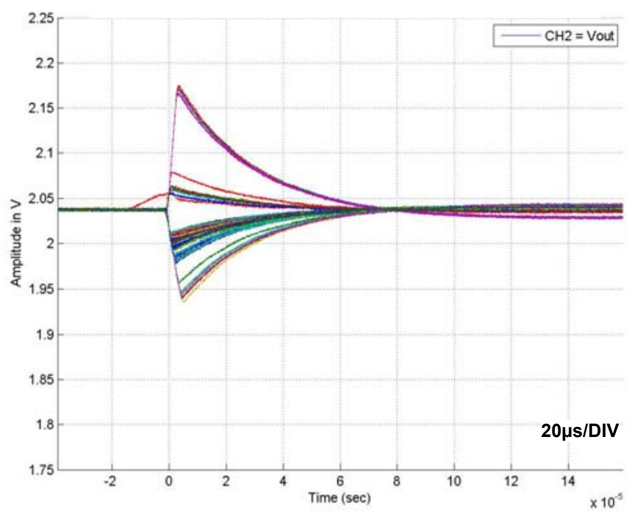

FIGURE 11. COMPOSITE (100) PLOT OF SET FOR ISL71091SEH20 AT LET 60 V_{IN} = 5.5V, I_{OUT} = 1mA, C_{OUT} = 1µF, C_{COMP} = 1nF. TRIGGER AT ±20mV.

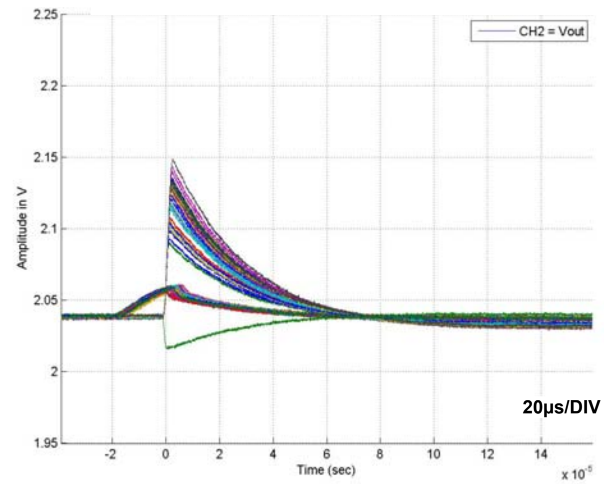

FIGURE 12. COMPOSITE (100) PLOT OF SET FOR ISL71091SEH20 AT LET = 28 V_{IN} = 16.5V, I_{OUT} = 1mA, C_{OUT} = 1µF, C_{COMP} = 1nF. TRIGGER AT ±20mV.

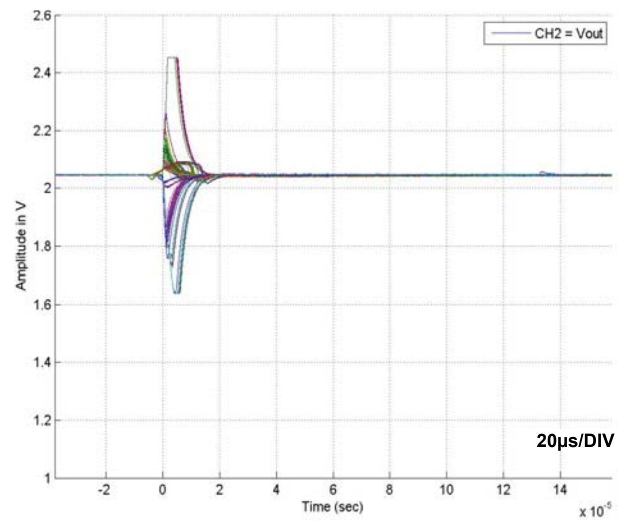

FIGURE 13. COMPOSITE PLOT OF 100 SET FOR ISL71091SEH20 at LET = 60, V_{IN} = 5.5V, I_{OUT} = 1mA, C_{OUT} = 0.1µF, C_{COMP} = 1nF. TRIGGER AT ±20mV AND SCOPE TRUNCATING SET AT ±400mV.

Even at V_{IN} = 5.5V the SET can exceed ±400mV with C_{OUT} = 0.1µF. Thus the SET performance is very much linked to both the selection of C_{OUT} and V_{IN}. Comparing Figure 13 to Figure 11 shows that the magnitude of the SET are reduced from greater than 400mV with C_{OUT} = 0.1µF (Figure 13) to less than 125mV (Figure 11), but the duration grows from under 20µs to about 200µs. Comparing Figure 12 to Figure 11 indicates that the magnitude of the SET does not diminish much with the reduction in ion LET from 60 to 28 MeV•cm^2/mg.

TABLE 4. SUMMARY OF SET TESTING ON ISL71091SEH40

				SET COUNTS (±20mV), 4e6 ion/cm^2			
				C_{OUT} = 0.1µF C_{COMP} = 1nF	C_{OUT} = 1µF C_{COMP} = 10nF	C_{OUT} = 10µF C_{COMP} = 10nF	
Run	LET MeV (mg/cm^2)	I_{OUT} (mA)	V_{IN} (V)	DUT 1	DUT 2	DUT 3	DUT 4
301	28	-5	6	1043	110	46	0
302			7.5	1042	66	36	0
303			30	**1021 (Figure 14)**	**34 (Figure 16)**	214	0
304		10	6	1270	50	60	0
305			7.5	1294	75	52	0
306			30	1144	**33 (Figure 17)**	**193 (Figure 19)**	0
201	8.5	-5	6	162	0	0	0
202			7.5	175	0	0	0
203			30	208	0	0	0
204		10	6	139	0	0	0
205			7.5	157	1	0	0
206			30	204	**2 (Figure 18)**	0	0

NOTE:
5. Bold entries correspond to composite SET plot in Figures 14 through 18.

SET Testing of ISL71091SEH40, 4.096V Reference

Four samples of the ISL71091SEH40 (4.096V reference) were tested for SET as summarized in Table 4. Parts were tested at both maximum sink (-5mA) and source current (10mA) at LET 28 and 8.5 MeV•cm^2/mg. SET captures were triggered at ±20mV deviation from DC.

There is a clear difference between DUT3 and DUT4 even though they had the same capacitance values. It was noted that the SET triggering on DUT3 were spikes of <10ns duration, (see Figure 20) so the difference was in registering these very short events. The oscilloscopes were swapped and the difference between DUT3 and DUT4 remained the same, so the difference was not the oscilloscope. Very likely the difference was due to a difference in the C_{OUT} impedance as dominated by PC board parasitics, but that is speculation.

It is clear that the decrease in LET from 28 to 8.5 MeV•cm^2/mg significantly reduced the number of SET reaching the ±20mV trigger threshold. Also, the selection of capacitor values had a strong influence on captures. At C_{OUT} = 1µF and C_{COMP} = 10nF SET reaching ±20mV were nearly eliminated for LET 8.5 MeV•cm^2/mg. With C_{OUT} = 10µF, no SET at all of ±20mV were recorded.

The SET counts for DUT1 runs 301 through 306 were very similar and the SET transients were of the form represented in Figure 14 which shows all the SET for run 303 and DUT1. A few large positive SET extended to a maximum of +520mV, and a single large negative SET reached 330mV. However, the vast majority of SET captured was within ±100mV. The major SET deviation was over in about 20µs with the tail extending about 100µs. These characteristics held for the other 300 series runs on DUT1.

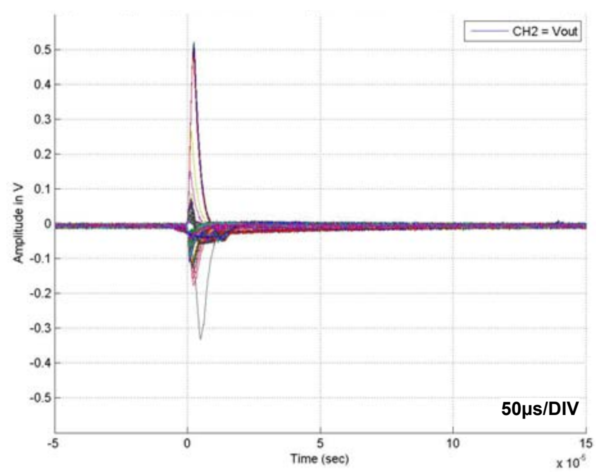

FIGURE 14. COMPOSITE PLOT OF 1021 SET FOR DUT1 RUN 303: C_{OUT} = 0.1µF, C_{COMP} = 1nF, I_{OUT} = -5mA, V_{IN} = 30V, LET = 28

A slightly different way to look at the SET is provided in Figure 15. It is clear in this view just how rare the larger SET's are. Virtually all the positive SET are between -175mV and +25mV; only a $6.75x10^{-6}$ cross section represents larger positive events. There were 27 events above +250mV out of 1021 total captures. Negative SET are almost all smaller than 200mV.

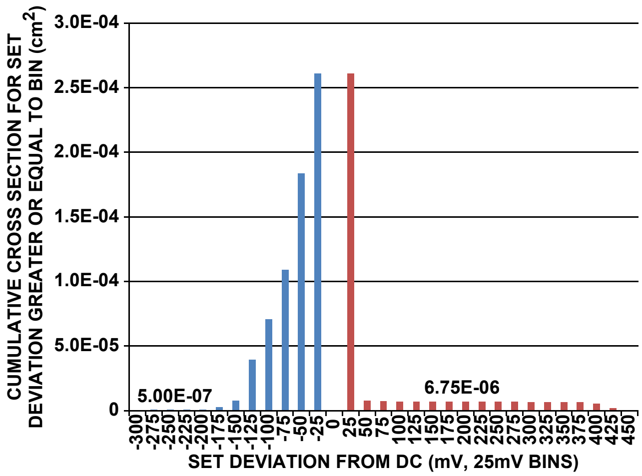

FIGURE 15. SUMMARY OF RUN 301 DUT1 SET CROSS SECTIONS BY DEVIATION. THE COLUMNS REPRESENT THE CROSS SECTION OF SET WITH DEVIATIONS LARGER THAN THE BIN THE COLUMN IS IN.

DUT2, with C_{OUT} = 1µF and C_{COMP} = 10nF, exhibited different SET characteristics from DUT1 as shown in Figure 16. The count of SET exceeding ±20mV is reduced by a factor of 30, and those captured were bounded by +75mV and -50mV and decayed in 100µs. Despite the higher SET counts for DUT2 on runs 301 and 302 the SET form was the same.

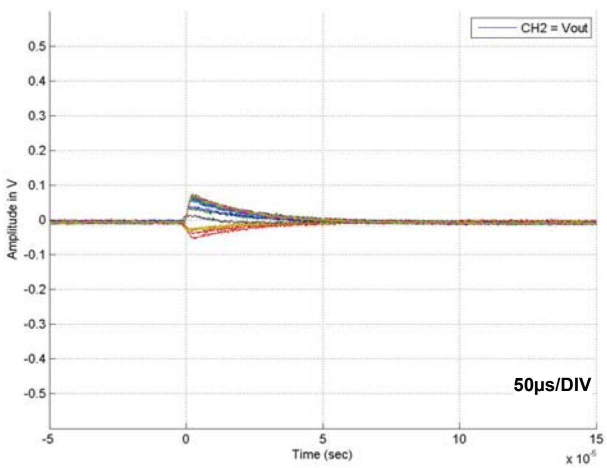

FIGURE 16. COMPOSITE PLOT OF 34 SET FOR DUT2 RUN 303: C_{OUT} = 1µF, C_{COMP} = 10nF, I_{OUT} = -5mA, V_{IN} = 30V, LET = 28

Figure 17 shows the form of the SET shifted with a change in load current from -5mA to +10mA. In this case the negative SET extended down to -90mV, but the positive SET were essentially unchanged at about +75mV.

When the LET was dropped to 8.5 MeV•cm^2/mg the SET reaching ±20mV on DUT2 virtually vanished. Figure 18 shows the only two SET recorded on DUT2 for run 206 and these barely made the ±20mV trigger level.

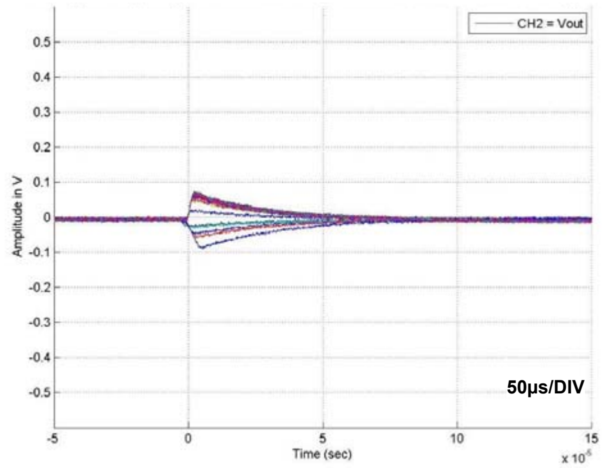

FIGURE 17. COMPOSITE PLOT OF 33 SET FOR DUT2 RUN 306: C_{OUT} = 1µF, C_{COMP} = 10nF, I_{OUT} = 10mA, V_{IN} = 30V, LET = 28

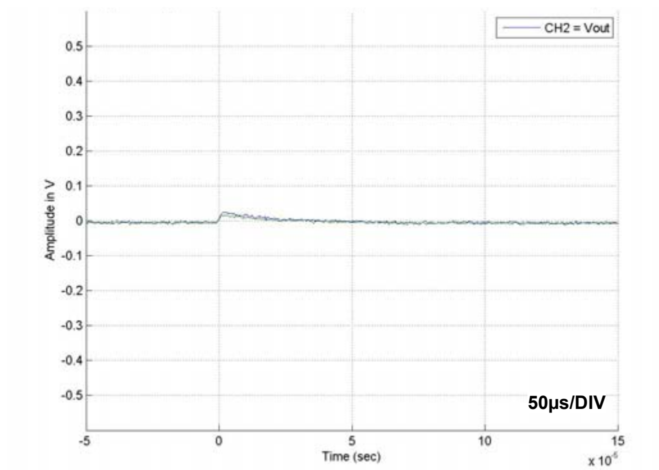

FIGURE 18. COMPOSITE PLOT OF THE 2 SET FOR DUT2 RUN 206: C_{OUT} = 1µF, C_{COMP} = 10nF, I_{OUT} = 10mA, V_{IN} = 30V, LET = 8.5

Finally, the SET for DUT3 (C_{OUT} = 10µF, C_{COMP} = 10nF) at LET = 28 MeV•cm^2/mg are shown in Figure 19. It should be noted that the time scale in Figure 19 is marked $1x10^{-6}$ seconds where as the previous plots were in $1x10^{-5}$ seconds. The plots in Figure 19 do not reach the ±20mV triggering levels due to the plotting software routine (MATLAB), filtering out the triggering event, which was very short and sharp. An example of the direct oscilloscope capture for DUT3 in run 301 is shown in Figure 20. Here it can be seen that the event triggering the oscilloscope was only about 10ns wide and negative.

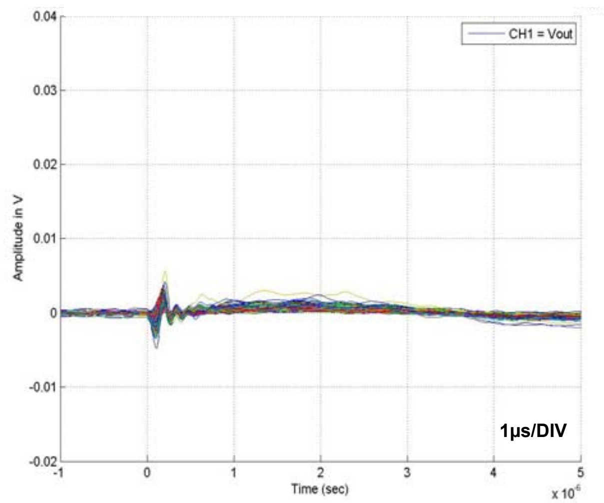

FIGURE 19. COMPOSITE PLOT OF THE 193 SET FOR DUT3 RUN 306: C_{OUT} = 10µF, C_{COMP} = 10nF, I_{OUT} = 10mA, V_{IN} = 30V, LET = 28

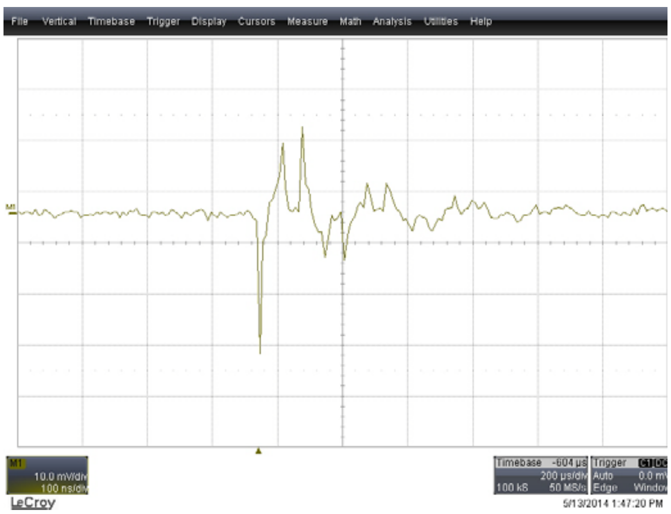

FIGURE 20. DIRECT OSCILLOSCOPE CAPTURE OF A DUT3 SET FROM RUN 301

SET Testing of ISL71091SEH10, 10.0V Reference

Four ISL71091SEH10 (10.0V) parts were initially SET tested as outlined in Table 5.

TABLE 5. SUMMARY OF SET TESTING OF ISL71091SEH10 SAMPLES

LET	C_{OUT} (µF)	C_{COMP} (nF)	VIN	PART A EVENTS (±100mV)	PART B EVENTS (±100mV)	NET CROSS SECTION (cm^2)
60	1	1	16.5	74	46	1.2E-05
60	0.1	1	16.5	419 (2962 Note 7)	441 (989 Note 7)	4.0E-04
60	1	1	13.2	79	64	1.4E-05
60	0.1	1	13.2	445 (2992 Note 7)	498 (1027 Note 7)	4.0E-04
28	1	1	16.5	0	0	–
28	0.1	1	16.5	81	93	1.7E-05
28	1	1	13.2	0	0	–
28	0.1	1	13.2	94	95	1.9E-05
8.5	1	1	16.5	0	0	–
8.5	0.1	1	16.5	1 (257 Note 7)	2 (49 Note 7)	3.1E-05
8.5	1	1	13.2	0	0	–
8.5	0.1	1	13.2	0 (234 Note 7)	0 (124 Note 7)	–

NOTES:

6. The I_{OUT} for each part was 1mA and the fluency for each irradiation was $5x10^6$ ion/cm^2.
7. Counts were captured with a ±20mV trigger.

The counts of ±100mV (±1%) SET were highly sensitive to the value of C_{OUT}. Figure 21 shows the plot of cross sections versus LET. The cross section at LET = 60 was reduced by almost an order of magnitude in going from C_{OUT} = 0.1µF to C_{OUT} = 1µF. The ±20mV (0.2%) SET were much more common but were not captured for all cases and are not converted to cross sections here.

Figures 22 and 23 provide comparison of the SET forms for the two different output capacitors, 0.1µF and 1µF. The SET with the smaller C_{OUT} value reach the oscilloscope clipping limits of ±400mV, but the SET for the larger C_{OUT} are maintained within ±200mV. However, the duration grows from 20µs to 100µs. There does not appear to be significant overshoot/undershoot in the case of C_{OUT} = 1µF that appears in case of the 2.048V reference.

Figure 24 shows that SET of significant magnitude (>300mV) are induced by ions with LET of 8.5 MeV•cm^2/mg. However, with C_{OUT} = 1µF all SET were suppressed to below the ±100mV triggering threshold for LET < 60. It appears that C_{OUT} = 1µF is sufficient to hold all 10V output SET within ±100mV for LET ≤ 28 MeV•cm^2/mg and I_{OUT} = 1mA. Both positive and negative SET's are in evidence at the 1mA output current. At LET = 60, SET larger than 100mV do occur.

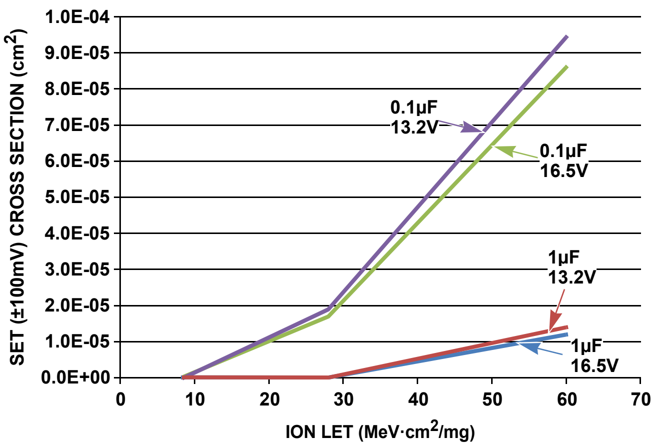

FIGURE 21. PLOT OF NOMINAL CROSS SECTION FOR THE VARIOUS CONDITIONS TESTED FOR THE ISL71091SEH10

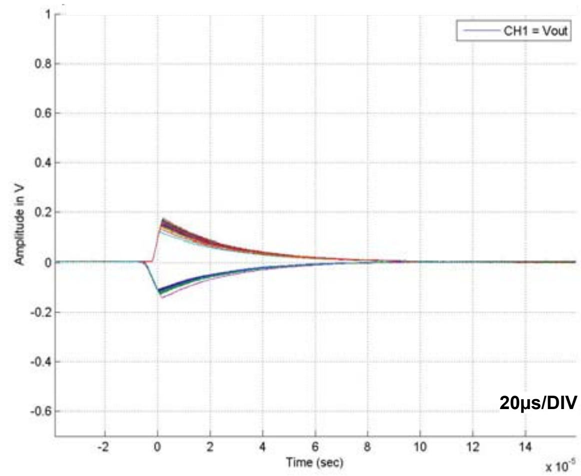

FIGURE 23. COMPOSITE (74) PLOT OF SET FOR ISL71091SEH10 AT LET = 60, V_{IN} = 16.5V, I_{OUT} = 1mA, C_{OUT} = 1µF, C_{COMP} = 1nF. CAPTURE TRIGGER AT ±100mV.

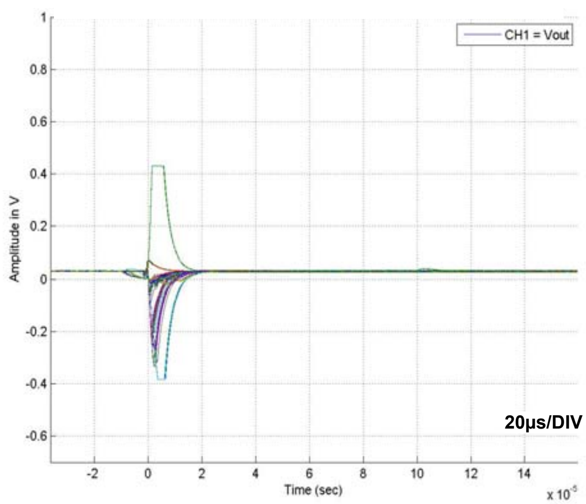

FIGURE 22. COMPOSITE PLOT OF 100 SET FOR ISL71091SEH10 AT LET = 60, V_{IN} = 16.5V, I_{OUT} = 1mA, C_{OUT} = 0.1µF, C_{COMP} = 1nF. CAPTURE TRIGGER AT ±20mV, SCOPE TRUNCATED SET AT ±400mV.

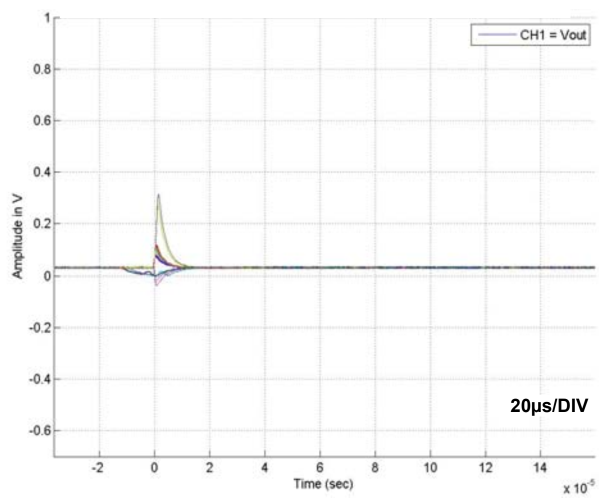

FIGURE 24. COMPOSITE (49) PLOT OF SET FOR ISL71091SEH10 AT LET = 8.5, V_{IN} = 16.5V, I_{OUT} = 1mA, C_{OUT} = 0.1µF, C_{COMP} = 1nF. CAPTURE TRIGGER AT ±20mV

Further SET testing was done on four additional parts of the ISL71091SEH10 to look at the lower LET and the impact of the capacitor selection. A summary of this testing is shown in Table 6.

TABLE 6. SUMMARY OF SECOND ROUND OF SET TESTING ON THE ISL71091SEH10

Run	LET	IOUT (mA)	VIN (V)	SET Counts (±20mV), 4e6 ion/cm^2			
				C_{OUT} = 0.1µF C_{COMP} = 1nF	C_{OUT} = 1µF C_{COMP} = 10nF	C_{OUT} = 10µF C_{COMP} = 10nF	
				DUT 1	DUT 2	DUT 3	DUT 4
311	28	-5	6	1129	58	183	13
312			7.5	1103	67	196	34
313			30	**952 (Figure 25)**	**38 (Figure 27)**	**435 (Figure 28)**	62
314		10	6	1229	70	162	9
315			7.5	1379	73	211	28
316			30	1219	39	437	59
211	8.5	-5	6	176	1	0	0
212			7.5	162	0	0	0
213			30	**154 (Figure 26)**	1	0	0
214		10	6	179	0	0	0
215			7.5	161	0	0	0
216			30	194	0	0	0

NOTE:

8. Bold entries correspond to composite SET plot in Figures 25 through 28.

Clearly the count of ±20mV SET is reduced considerably in going from C_{OUT} = 0.1µF and C_{COMP} = 1nF to C_{OUT} = 1µF and C_{COMP} = 10nF. The change going from C_{OUT} = 1µF to C_{OUT} = 10µF is less clear due to the discrepancy between DUT3 and DUT4. This difference mimics the difference between DUT3 and DUT4 of the 4.096V reference.

Figure 25 displays the 952 events registered for run 313 on DUT1. The similarity of these SET with those observed for the 4.096V reference (Figure 14) is clear, even to the deviations of the SET.

Reducing the LET to 8.5 MeV•cm^2/mg reduces the SET magnitudes as well as the ±20mV SET counts (952 to 154) as shown in Figure 26. Clearly the LET determines the magnitude of the resulting SET. Although one SET reached +270mV and one reached -75mV, the rest of the SET were bounded by +100mV and -50mV.

The impact of changing C_{OUT} to 1µF and C_{COMP} to 10nF is apparent in Figure 27 (run 313 DUT2). Not only has the SET count dropped from 952 to 38, but the extremes of the SET have dropped to +75mV and -60mV. This is virtually identical to the case of the 4.096V reference depicted in Figure 16.

For the case of C_{OUT} = 10µF and C_{COMP} = 10nF the 10V reference again correlates with the 4.096V reference in that SET under 5mV register on the plotting diagrams.

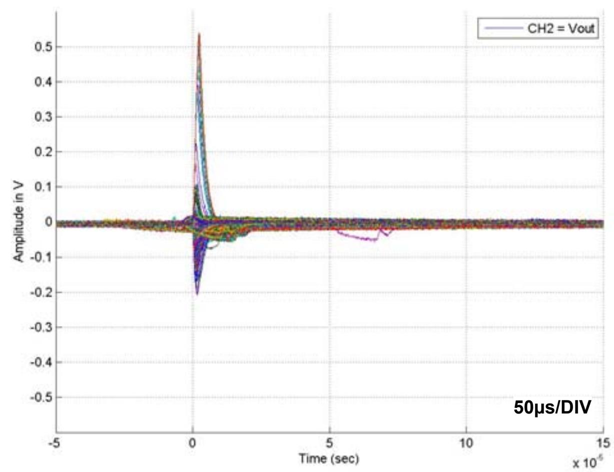

FIGURE 25. COMPOSITE PLOT OF 952 SET FROM RUN 313 ON DUT1: C_{OUT} = 0.1µF, C_{COMP} = 1nF, I_{OUT} = 10mV, V_{IN} = 30V, LET = 28

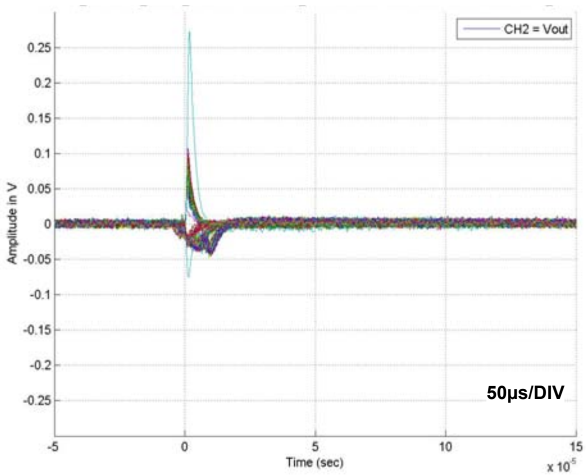

FIGURE 26. COMPOSITE PLOT OF 154 SET FROM RUN 213 DUT1: C_{OUT} = 0.1µF, C_{COMP} = 1nF, I_{OUT} = -5mA, V_{IN} = 30V, LET = 8.5.

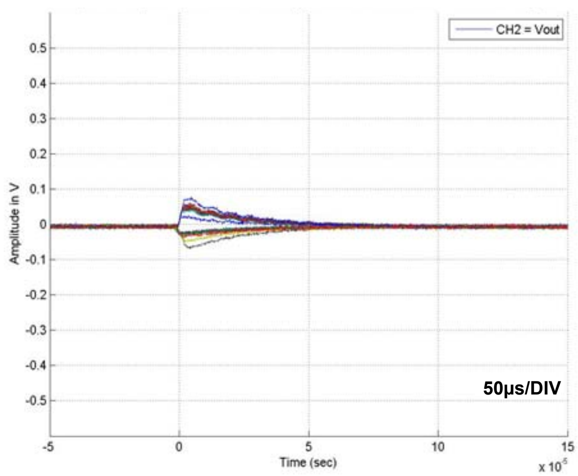

FIGURE 27. COMPOSITE PLOT OF 38 SET FROM RUN 313 DUT2: C_{OUT} = 1µF, C_{COMP} = 10nF, I_{OUT} = -5mA, V_{IN} = 30V, LET = 28.

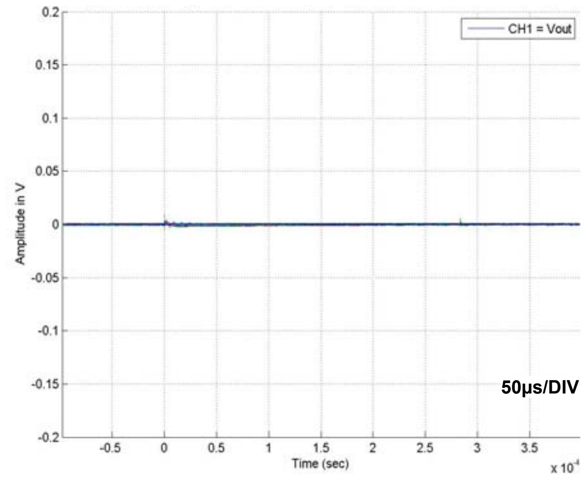

FIGURE 28. COMPOSITE PLOT OF 435 SET FROM RUN 313 DUT3: C_{OUT} = 10µF, C_{COMP} = 10nF, I_{OUT} = -5mA, V_{IN} = 30V, LET = 28

Conclusions

SEE testing of the ISL71091SEH precision reference product family has demonstrated that the devices are immune to SEB and SEL to an LET of 86.4 MeV•cm^2/mg with an input voltage up to 36V and a load current of either -5mA or +10mA. This represents a supply voltage 20% over the recommended maximum operation of 30V and at the limits of the recommended output drive current capability. Although SEB/SEL (destructive ion testing) was only done on the 3.3V version (ISL71091SEH33) these results apply to all of the ISL71091SEHxx family since they share the same silicon design.

SET testing demonstrated that a larger C_{OUT} serves to suppress the SET deviation magnitude but brings some jeopardy. A C_{OUT} = 10µF was very effective in limiting SET at LET = 28 MeV•cm^2/mg as can be best seen in the results for the 4.096V and 10.0V references. However, at LET = 60 MeV•cm^2/mg and V_{IN} = 16.5V on the 3.3V and 2.048V references a large and long SET form appeared (Figures 3 and 9). This implies a compromise with capacitor selection and SET performance.

If large and short (±500mV and 25µs) SET in response to relatively low LET (≤28 MeV•cm^2/mg) can be tolerated, the minimal capacitance values of C_{OUT} = 0.1µF and C_{COMP} = 1nF can be used. However, if suppression of these common events is needed, going to C_{OUT} = 10µF and C_{COMP} = 10nF virtually eliminates the SET but opens up the potential for rarer events at higher LET and V_{IN} (>13.2V), which are large (several hundred millivolts) and long (~1ms).

There is not a clear “best” choice of capacitance values as every choice brings with it an SET consequence. The user is encouraged to carefully review the data presented in the report in considering and deciding upon the V_{IN}, C_{OUT}, and C_{COMP} values to be used in an application.

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