ISL70517SEH, ISL70617SEH

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). 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 ISL70617SEH and ISL70517SEH instrumentation amplifiers.

Product Description

The ISL70617SEH is a differential output instrumentation amplifier. The ISL70517SEH is a single-ended output instrumentation amplifier based on the ISL70617SEH. The ISL70617SEH and ISL70517SEH parts are metal mask and bond options of the same silicon die. Further description and explanation of the differences between the parts can be found in the datasheets.

Product Documentation

ISL70617SEH datasheet

ISL70517SEH datasheet

Standard Microcircuit Drawing (SMD): 5962-15246

SEE Test Objectives

The ISL70617SEH and ISL70517SEH were both tested to determine their susceptibility to destructive single event effects (referred to herein as SEB) and to characterize their Single Event Transient (SET) behavior over different operating conditions.

SEE Test Facility

Testing was performed at the Texas A&M University (TAMU) Radiation Effects Facility of the Cyclotron Institute heavy ion facility. This facility is coupled to a K500 super conducting cyclotron, which is capable of generating a wide range of particle beams with the various energy, flux, and fluence levels needed for advanced radiation testing. Further details on the test facility can be found at the website (http://cyclotron.tamu.edu/). The Devices Under Test (DUTs) were located in air at 30mm from the aramica window for the ion beam. Ion LET values are quoted at the DUT surface. Signals were communicated to and from the DUT test fixture through 20 foot cables connecting to the control room. Testing was carried out on June 2, 2015.

SEE Test Set-Up

SEE testing was carried out with the samples in an active configuration. The schematic of the ISL70617SEH SEE test fixture is shown in Figure 1. The indicated 150kΩ R3 (sense resistor) was replaced with a 15kΩ for a gain of 10 and the jumper J13 was not in place. Direct oscilloscope connection to the $+V_{OUT}$ and $-V_{OUT}$ outputs were provided through the 20 foot cables from the irradiation cave to the control room.

Two instantiations of the schematic on a single board allowed two ISL70617SEH to be simultaneously irradiated for SEE testing. The two parts were monitored separately. Parts were in standard flatpack packages but had their lids removed for the SEE testing. For SEB the parts' combined supply currents (IVCC and IVCO and IVEE and IVEO) and output voltages ($+V_{OUT}$ and $-V_{OUT}$) were monitored for equal inputs (IN+ and IN-) at a rail. For SET testing, the outputs of $\pm V_{OUT}$ were both monitored via separate oscilloscopes for transients. The transient trigger was set for ±1V, and any transient reaching 1V or greater deviation triggered an oscilloscope capture that included both outputs. These captures were later reviewed via post processing with MATLAB.

The parts tested came from the First Of Kind (FOK) lot X4H8X using mask set TA54254 on the Intersil PR40 process in FAB59.

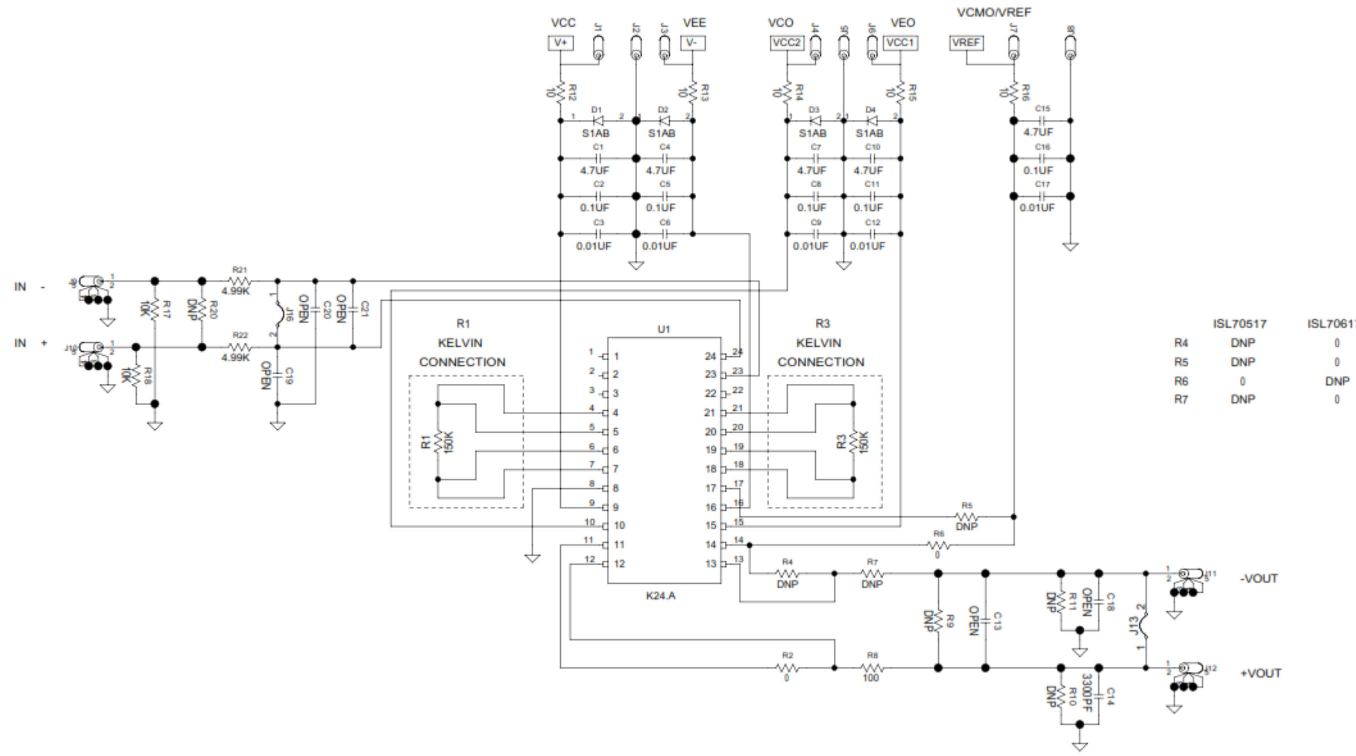

FIGURE 1. SCHEMATIC OF THE ISL70617SEH SEE TEST CONFIGURATION. CONNECTORS GO TO 20 FOOT CABLE TO CONTROL ROOM.

SEB Testing of the ISL70617SEH Instrumentation Amplifier with Pr (LET = 60)

For SEB testing of the ISL70617SEH and ISl70517SEH the input and output supplies were set to equal and symmetric voltages (±V) and the differential inputs were driven to opposite rails so that the part was under equivalent voltage stress on both the input and output stages. The combined (two DUT's at a time) supply and input currents were measured before and after the irradiations to look for any changes due to irradiation. The output voltages were also monitored for the case of inputs tied together to the negative supply rail. Irradiation for was done with 2.114GeV praseodymium (Pr) at a 10° incidence for an effective LET at the die surface of 60MeV•cm^2/mg to a fluence of $5x10^6$ ion/cm^{-2} at a flux of $2.5x10^4$ ion/(cm^2s).

For the ISL70617SEH the supply rails were started at ±18V and incremented by 1V on the first pair of DUT's and they survived through ±22V. The second pair of ISL70617 started at ±20V and survived through ±22V. The summary observations for ±22V biasing case are presented in Table 1 for the currents and Table 2 for the output voltages.

Because the ISL70517SEH is based on the same silicon die as the ISL70617SEH, the SEB testing of the ISL70517SEH started with the supplies at the ±22V setting with the full expectation of achieving the same results as with the ISL70617SEH. The positive results confirming that expectation are presented in Tables 3 and 4 on page 3.

It was concluded that for irradiation with ions of LET = 60MeV•cm^2/mg the parts, both ISL70617SEH and ISL70517SEH did not suffer permanent damage up to supplies and input signals of ±22V.

TABLE 1. ISL70617SEH SEB MONITOR FOR V_{CC} = V_{CO} = 22V and V_{EE} = V_{EO} = -22V AND V_{IN}+ = 22V AND V_{IN-} = -22V and EFFECTIVE LET = 60MeV•cm^2/mg TO A FLUENCE OF $5x10^6$ cm^{-2} WITH T_{CASE} = +125°C ±10°C.

DEVICES UNDER TEST	TEST	IVCC + IVCO (mA)	IVEE + IVEO (mA)	IIN+ (nA)	IIN- (nA)
DUT1 and DUT2	Pre	14.86	9.76	10.00	4.88
	Post	14.86	9.76	10.03	4.89
DUT3 and DUT4	Pre	14.55	9.44	10.03	4.87
	Post	14.55	9.43	10.04	4.88

TABLE 2. ISL70617SEH SEB MONITOR FOR V_{CC} = V_{CO} = 22V and V_{EE} = V_{EO} = -22V AND V_{IN}+ = 22V and V_{IN}- = -22V and EFFECTIVE LET = 60MeV•cm^2/mg TO A FLUENCE OF $5x10^6$ cm^{-2} WITH T_{CASE} = +125°C ±10°C. OUTPUT VOLTAGES WERE MEASURED WITH BOTH INPUTS AT V_{IN}+ = V_{IN}- = -22V.

DEVICES UNDER TEST	TEST	+VOUT (mV)	-VOUT (mV)	DIFFERENCE (mV)
DUT1	Pre	526	520	6
	Post	534	526	8
DUT2	Pre	92	96	-4
	Post	96	94	2
DUT3	Pre	268	264	4
	Post	275	271	4
DUT4	Pre	371	371	0
	Post	379	377	2

TABLE 3. ISL70517SEH SEB MONITOR FOR V_{CC} = V_{CO} = 22V and V_{EE} = V_{EO} = -22V and V_{IN}+ = 22V and V_{IN}- = -22V and EFFECTIVE LET = 60MeV•cm^2/mg TO A FLUENCE OF $5x10^6$ cm^{-2} with T_{CASE} = +125°C ±10°C.

DEVICES UNDER TEST	TEST	IVCC + IVCO (mA)	IVEE + IVEO (mA)	IIN+ (nA)	IIN- (nA)
DUT1 and DUT2	Pre	17.36	12.37	10.04	4.99
	Post	17.33	12.34	10.04	4.99
DUT3 and DUT4	Pre	17.46	8.54	10.07	4.99
	Post	17.43	8.55	10.09	4.99

TABLE 4. ISL70517SEH SEB MONITOR FOR V_{CC} = V_{CO} = 22V and V_{EE} = V_{EO} = -22V and V_{IN}+ = 22V and V_{IN}- = -22V and EFFECTIVE LET = 60MeV•cm^2/mg TO A FLUENCE OF $5x10^6$ cm^{-2} with T_{CASE} = +125°C ±10°C. OUTPUT VOLTAGES WERE MEASURED WITH BOTH INPUTS AT V_{IN}+ = V_{IN}- = -22V.

DEVICES UNDER TEST	TEST	+VOUT (mV)
DUT1	Pre	1180
	Post	1180
DUT2	Pre	168
	Post	174
DUT3	Pre	987
	Post	993
DUT4	Pre	912
	Post	921

SET Testing of the ISL70617SEH Instrumentation Amplifier

SEE testing for non-destructive effects focused on SET of the outputs. SET were critiqued with a ±1V trigger on the oscilloscopes, which captured both $+V_{OUT}$ and $-V_{OUT}$ upon triggering on either output. It should be noted that at first it was attempted to take SET data with supplies at ±4V, but the part immediately went into oscillation when the ion beam started. It was found that increasing the supply to ±5V allowed the part to operate without continuous oscillation, but as the data will show this was an only marginally stable situation. The event counts for the various conditions and units is summarized in Table 5.

Combining the data for the four units tested and calculating the nominal ±1V event cross-sections led to the data listed in Table 6. The cross-sections reduced by an order of magnitude when going from LET = 59MeV•cm^2/mg down to 8.5MeV•cm^2/mg. This extrapolates the ±1V SET threshold down to the 2 to 3MeV•cm^2/mg range.

TABLE 5. ISL70617SEH ±1V SET COUNTS BY OUTPUT, DUT, ION LET, AND SUPPLY VOLTAGES. EACH IRRADIATION WAS TO $4x10^6$ ion/cm^2 AT ROOM TEMPERATURE WITH RFB = 150kΩ, R_{IN} = 15kΩ, V_{IN}± = 0V.

ION LET IN MeV•cm^2/mg AND SUPPLY VOLTAGES	±1V + V_{OUT} SET COUNTS				±1V - V_{OUT} SET COUNTS			
	DUT1	DUT2	DUT3	DUT4	DUT1	DUT2	DUT3	DUT4
LET = 59, ±5V	1464	1642	1914	1681	1567	1698	1678	1753
LET = 59, ±21V	1827	1975	2092	2086	1921	2019	1943	2196
LET = 8.5, ±5V	177	121	292	147	171	125	184	166
LET = 8.5, ±21V	221	163	305	210	203	169	184	225

TABLE 6. NOMINAL CROSS SECTIONS FOR THE ±1V SET EVENTS CAPTURED

ION LET AND SUPPLY VOLTAGES	±1V SET CROSS-SECTIONS (cm^2)	
	+VOUT	-VOUT
LET = 59, ±5V	4.2E-04	4.2E-04
LET = 59, ±21V	5.0E-04	5.0E-04
LET = 8.5, ±5V	4.6E-05	4.0E-05
LET = 8.5, ±21V	5.6E-05	4.9E-05

SET Traces

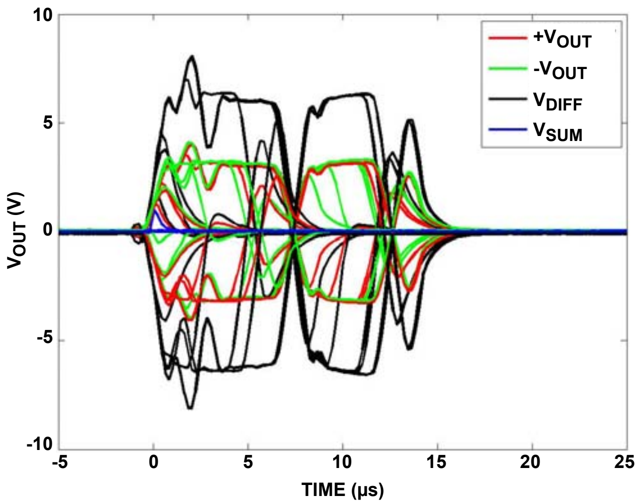

FIGURE 2A.

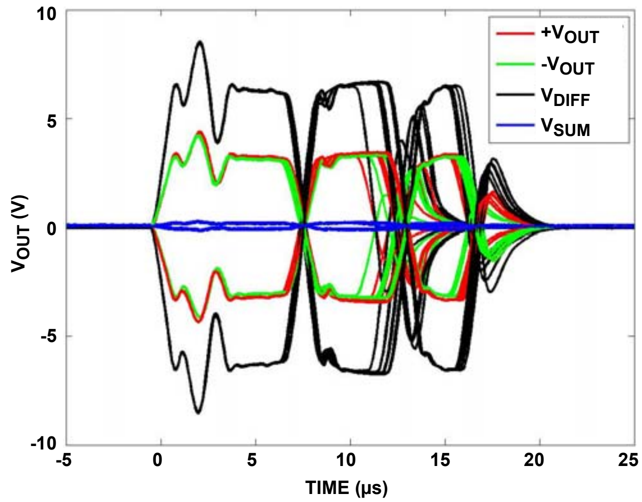

FIGURE 2B.

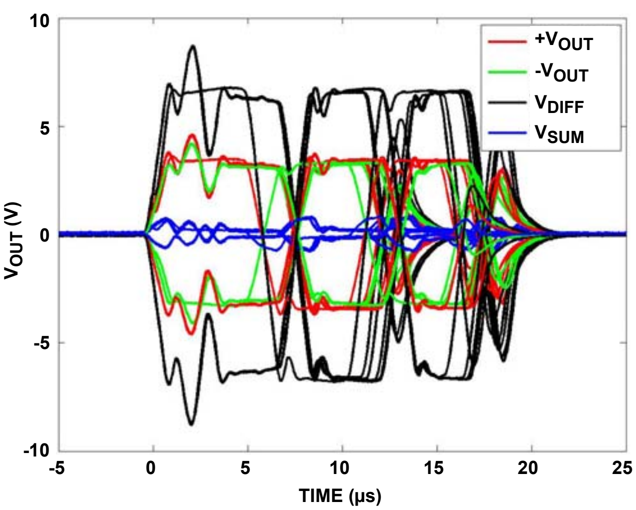

FIGURE 2C.

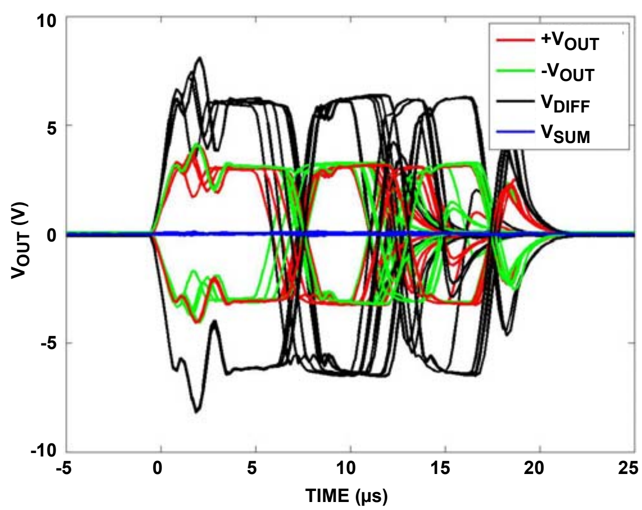

FIGURE 2D.

FIGURE 2. Plots of the 5 largest and longest SET for both polarities of +V_{OUT} maximum deviation for the four parts run at ±5V with LET = 59 MeV•cm^2/mg at 2x10^4 ion/(cm^2•s) to 4x10^6 ion/cm^2.

SET Traces (Continued)

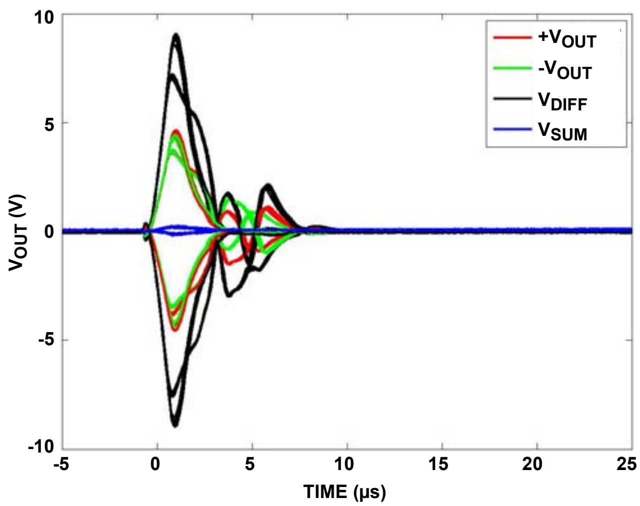

FIGURE 3A.

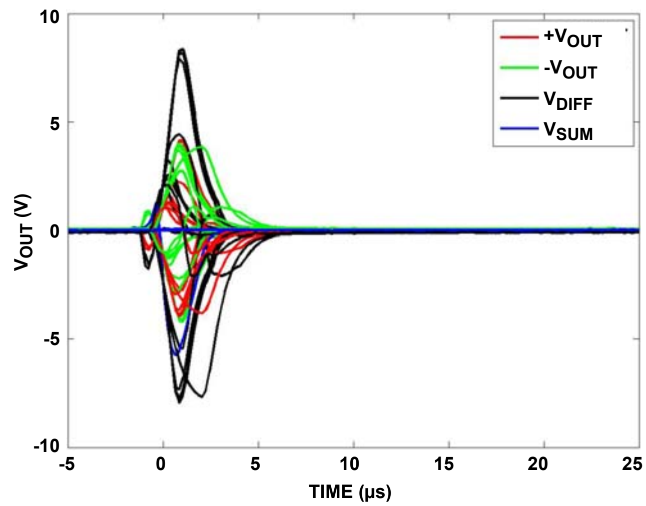

FIGURE 3B.

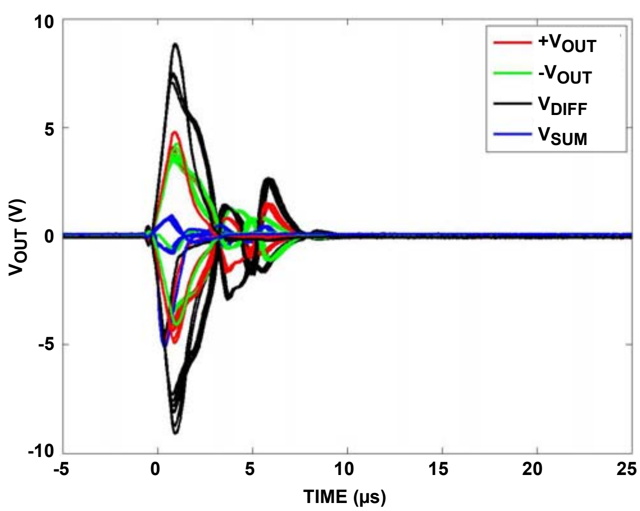

FIGURE 3C.

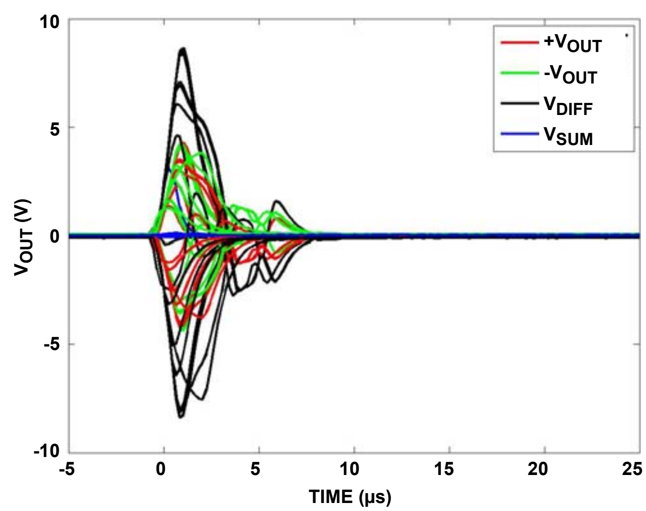

FIGURE 3D.

FIGURE 3. Plots of the 5 largest and longest SET for both polarities of $+V_{OUT}$ maximum deviation for the four parts run at ±21V with LET = 59 MeV•cm^2/mg at 2x10^4 ion/(cm^2•s) to 4x10^6 ion/cm^2.

SET Traces (Continued)

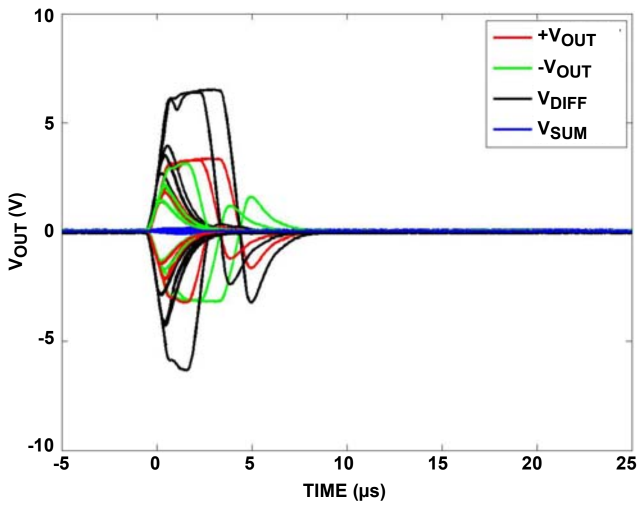

FIGURE 4A.

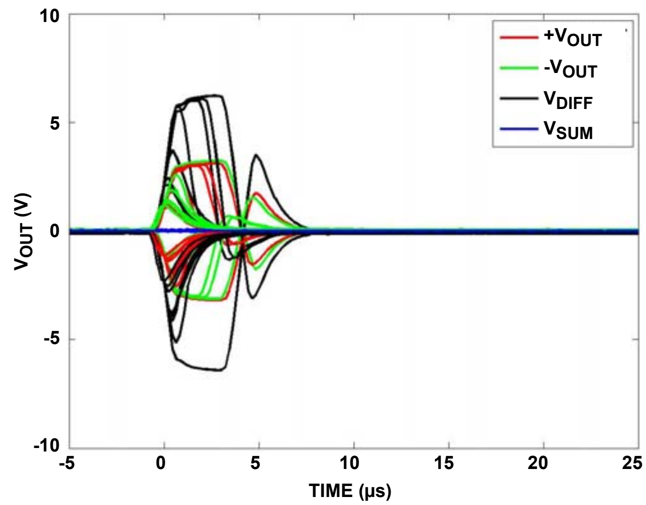

FIGURE 4B.

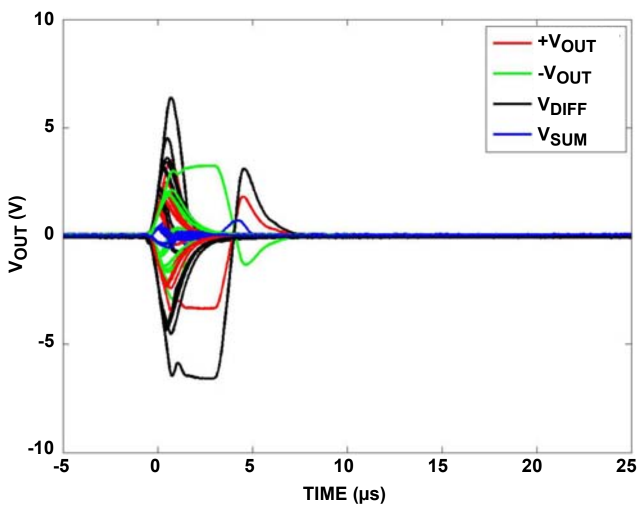

FIGURE 4C.

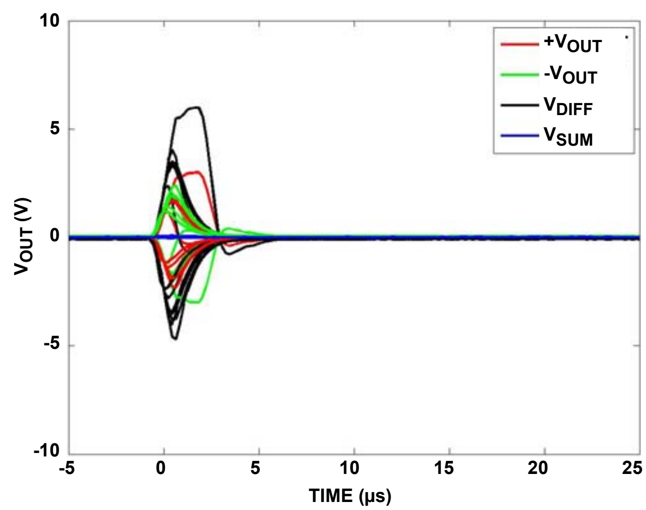

FIGURE 4D.

FIGURE 4. Plots of the 5 largest and longest SET for both polarities of $+V_{OUT}$ maximum deviation for the four parts run at ±5V with LET = 8.5 MeV • cm^2/mg at $2x10^4$ ion/(cm^2 • s) to $4x10^6$ ion/cm^2.

SET Traces (Continued)

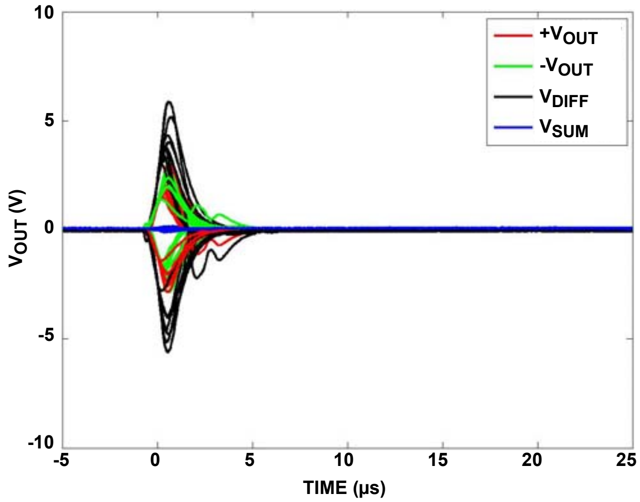

FIGURE 5A.

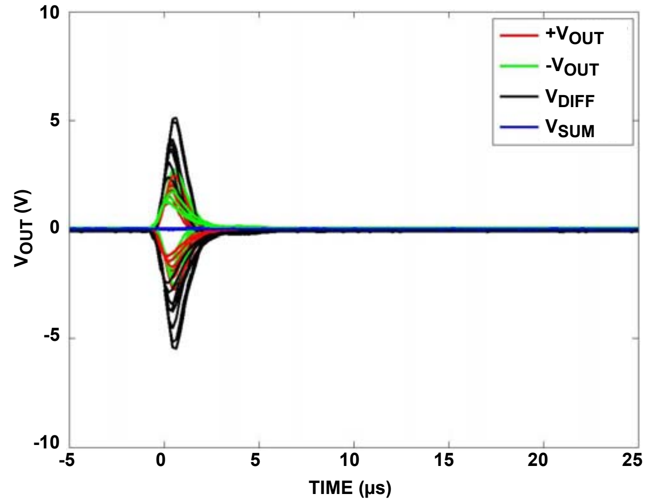

FIGURE 5B.

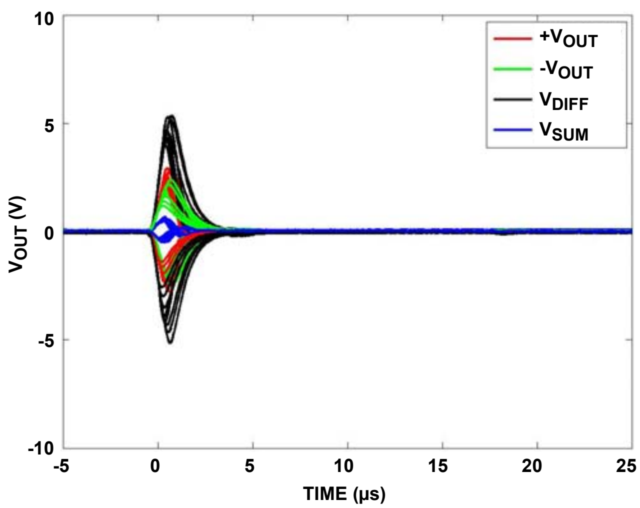

FIGURE 5C.

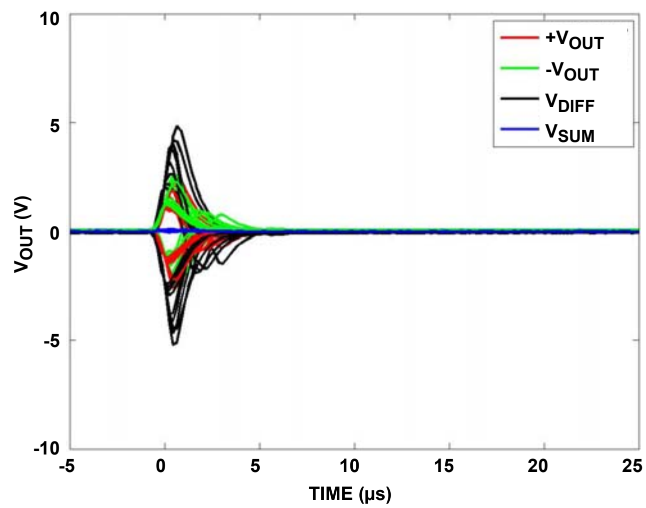

FIGURE 5D.

FIGURE 5. Plots of the 5 largest and longest SET for both polarities of $+V_{OUT}$ maximum deviation7 for the four parts run at ±21V with LET = 8.5 MeV•cm^2/mg at 2x10^4 ion/(cm^2•s) to 4x10^6 ion/cm^2.

The captured SET traces were post processed in MATLAB to apply some digital filtering and extract the worst case SET for presentation. Composite plots of the SET are presented in Figures 2 through 5.

The SET in Figure 2 takes the distinctive form of a few cycles of an oscillating behavior before the SET proceeds to die out in under 25µs. There is some part to part variability evident. This large SET time is more a function of the marginal stability of the part under the test conditions than it is a measure of the actual SET duration. The oscillatory behavior dominates the worst case SET performance. The oscillating behavior prohibited the testing at ±4V supplies as the beam created a continuous oscillation, though without the beam no oscillation was observed. This may indicate that lower fluxes are necessary to get true SET performance at the low supply voltages. Noting the near zero common-mode (V_{SUM}) indicates that the differential outputs are reacting oppositely to the SET. The actual SET duration is better measured in the SET data collected at ±21V supplies and presented in Figure 3.

At the higher supply settings of ±21V the differential SET approaches a 9V magnitude but is not over in 10µs duration. Although some SET exhibited some oscillatory behavior, the sustained oscillations seen at the lower supply did not repeat.

The SET results at the lower LET of 8.5MeV•cm^2/mg were not only less frequent but also of somewhat more benign magnitude and duration. Figure 4 shows the ±5V supply case and shows a reduced but still evident propensity for the oscillatory behavior noted at LET = 59MeV•cm^2/mg and ±5V. Even with that the SET are over in 10µs from onset.

The results for ±21V supplies and LET = 8.5MeV•cm^2/mg are presented in Figure 5 and show a much reduced magnitude and duration as compared to the results of LET = 59MeV•cm^2/mg. In this case the SET are over in approximately 7µs and reach a maximum differential magnitude of about 6V.

Conclusions

The ISL70617SEH and ISL70517SEH instrumentation amplifiers are immune to destructive SEE to effective LET = 60MeV•cm^2/mg over their full operational voltage range to ±22V. This is at least proved true to the composite fluence of 4x10^7 ions/cm^2 distributed over four units of each type tested for a nominal cross section limit of less than 1.25x10^{-8}cm^2.

The ISL70617SEH is susceptible to large output SET at LET of both 59 and 8.5MeV•cm^2/mg. At supplies of ±5V the parts exhibited a tendency to oscillate in response to the ion beam and SET, especially at the larger LET. It is believed that the oscillation was a function of the ion beam flux as the parts oscillated continuously at supplies of ±4V while the beam was on but did not oscillate without the beam. At ±21V supplies the propensity toward oscillatory responses was much reduced if not eliminated.

SET with <1V magnitude on +V_{OUT} (at a gain of 10 with zero inputs) exhibited a cross section of 5x10^{-4}cm^2 at LET = 59MeV•cm^2/mg and less than 6x10^{-5}cm^2 at LET = 8.5MeV•cm^2/mg. Extrapolation back from these two points indicates an event threshold of 1.6MeV•cm^2/mg. Testing at a lower LET is indicated in order to verify this.

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Refer to "http://www.renesas.com/" for the latest and detailed information.

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