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TEST REPORT

# ISL70219ASEH

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) 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 ISL70219ASEH dual operational amplifier.

Throughout this document reference is made to linear energy transfer (LET) and the units of this parameter is always understood to be $MeV \cdot cm^2/mg$.

## Product Description

The ISL70219ASEH is a dual version of the ISL70419SEH quad high performance operational amplifier and is fabricated in Intersil's 40V bonded wafer SOI process with deep trench isolation for precision bipolar analog products. The ISL70219ASEH is a metal variation of the ISL70419SEH die that only connects two of the four amplifiers on the die. Consequently, the ISL70219ASEH is identical in silicon to two of the ISL70419SEH amplifiers.

## Product Documentation

For more information about the ISL70219ASEH, refer to the documentation shown in following.

## Related Literature

ISL70219ASEH datasheet

ISL70219ASEH SMD 5962-14226

ISL70419SEH datasheet

AN1944, "Single Events Effects Report"

UG007, "ISL70219ASEHEV1Z Evaluation Board User Guide"

## SEE Test Objectives

The ISL70219ASEH was tested to determine its susceptibility to single event burnout (SEB, destructive ion effects) and to characterize its single event transient (SET) behavior over different operating conditions and over several 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 particle beams 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 ISL70219ASEH SEE test fixture is shown in Figure 1. It is the same configuration used for testing another dual amplifier, the ISL70244SEH. Four instantiations of the schematic allowed four ISL70219ASEH to be mounted on a board for simultaneous heavy ion irradiation. For SEB the sum of the four ISL70219ASEH supply currents were monitored before, during and after each irradiation to look for damage resulting in changes in supply current. Both outputs of each ISL70219ASEH were summed through another operational amplifier (not being irradiated). These summed outputs were also monitored for change in the SEB testing. For SET, the summed output provided a trigger signal for an oscilloscope that then captured and stored both individual amplifier outputs. In this way, four oscilloscopes were able to monitor and capture SET in both channels of all four dual operational amplifiers under test.

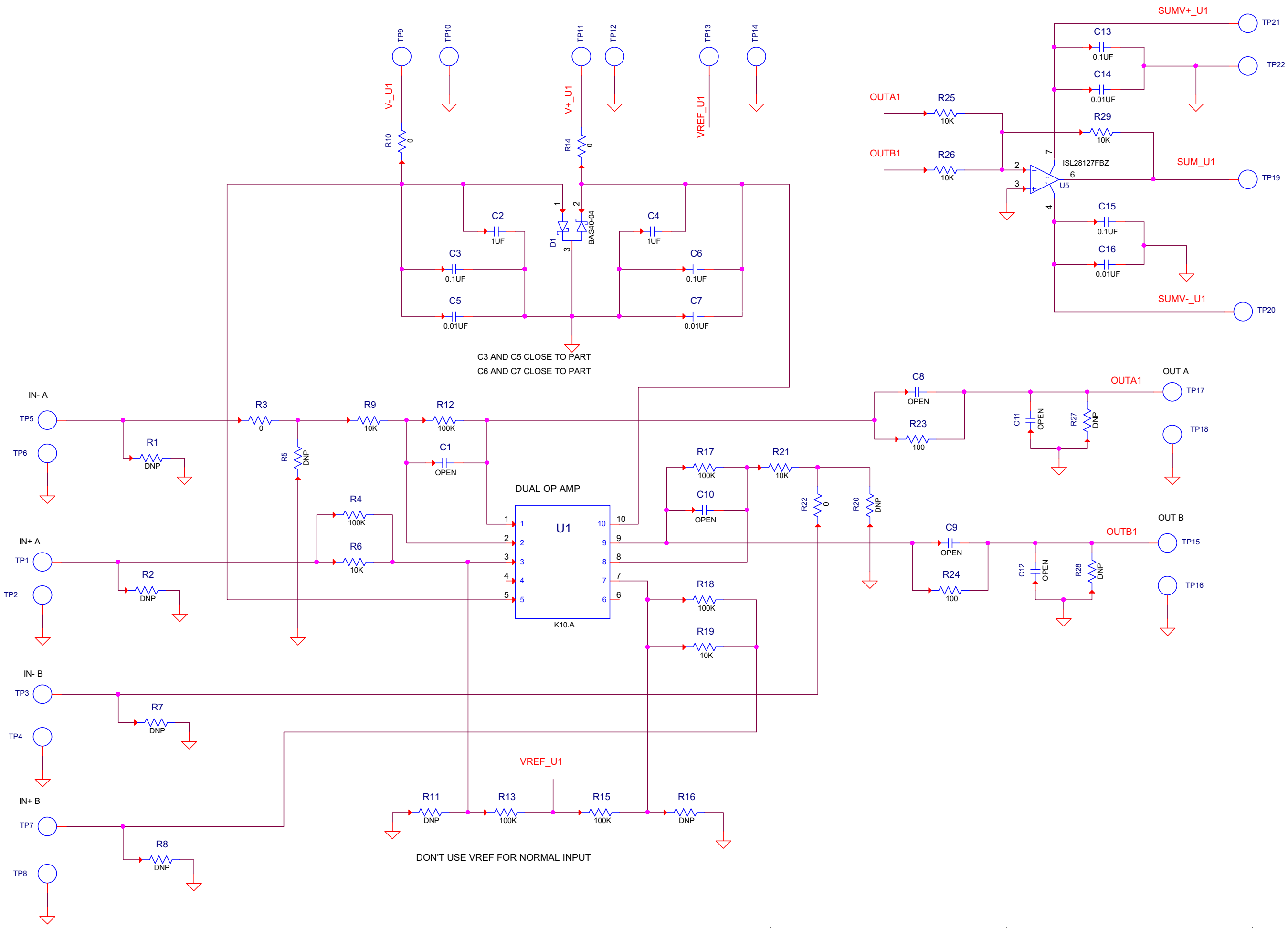


**FIGURE 1. SCHEMATIC OF THE ISL70219ASEH SEE TEST CIRCUIT**

## SEB Testing of the ISL70219ASEH Dual Operational Amplifier

Four ISL70219ASEH units on a single board were irradiated simultaneously with the summed supply currents and the summed dual outputs of each unit, monitored pre and post irradiation for change. Significant changes in output or current were deemed indications of permanent damage caused by the combination of voltage stress and ion impact. The supply voltage was varied to identify the limit when combined with ions of LET = 86 MeV•$cm^2$/mg. The results are presented in Table 1. The parts survived ±17V and ±18V while one unit failed at ±18.5V under irradiation.

## SET Testing of the ISL70219ASEH Dual Operational Amplifier

The parts were tested for SET four at a time as in the SEB testing. The dual amplifiers of each device were summed through another (non-irradiated) amplifier to provide an oscilloscope trigger signal if either operational amplifier experienced an SET at the output. The individual channels were then monitored on two other oscilloscope channels. The scope traces were captured and stored for later processing. Table 2 summarizes the SET testing done.

An error was made on run 302 and the oscilloscope ranges were left to accommodate the ±2.25V tests and so captures were clipped at the oscilloscope range limit of about ±2V. The marked disparity in capture counts reflects differences in the oscilloscopes that were used, each DUT using one oscilloscope. This makes the ratio of the event counts to the fluence only a lower bound on the effective cross section represented by the device. Post processing the data for SET that exceeded ±100mV deviation and selecting the largest event counts out of the eight channels on the four units tested for each LET and dividing by the beam fluence, yielded the lower bound for ±100mV SET cross sections as depicted in Figure 2. The values represent the cross section lower bound of an individual amplifiers since they are based on the individual channel outputs events of ±100mV or larger. It should be noted that these cross sections for ±100mV events differ substantially from those for the ±20mV event counts in Table 2 as many events fell into the range between ±20mV and ±100mV. These are also smaller than the cross sections reported in AN1944, “Single Event Effects Testing of the ISL70419SEH”. Those cross sections are for ±200mV events and are for the entire part (any of four channels).

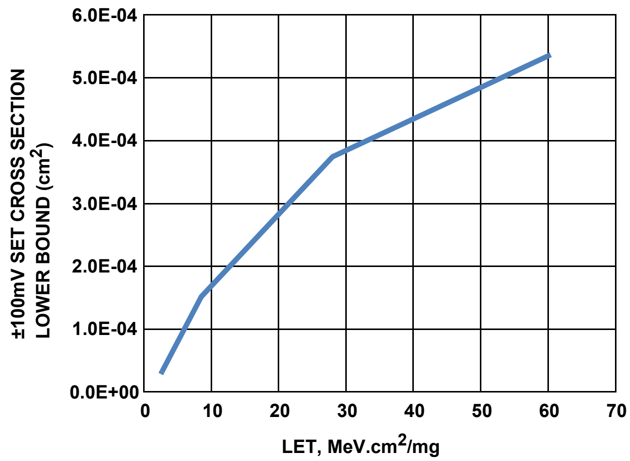


FIGURE 2. CROSS SECTION LOWER BOUND OF ±100mV DEVIATION SET PER AMPLIFIER vs LET

TABLE 1. SUMMARY OF SEB TESTING OF THE ISL70219ASEH

| RUN | DUT | GAIN | VIN (V) | VS± (V) | SUM ICC+ (mA) PRE | SUM ICC+ (mA) POST | SUM ICC- (mA) PRE | SUM ICC- (mA) POST | $V_{OUT}$ SUM (V) PRE | $V_{OUT}$ SUM (V) POST |
|---|---|---|---|---|---|---|---|---|---|---|
| 801 | 1 | 1 | 0.1 | ±17 | 6.059 | 6.053 | 5.534 | 5.529 | 0.2003 | 0.2002 |
| | 2 | | | | | | | | 0.2004 | 0.2004 |
| | 3 | 10 | | | | | | | 2.231 | 2.231 |
| | 4 | | | | | | | | 2.224 | 2.223 |
| 802 | 1 | 1 | 0.1 | ±18 | 6.071 | 6.069 | 5.545 | 5.544 | 0.2001 | 0.2002 |
| | 2 | | | | | | | | 0.2002 | 0.2003 |
| | 3 | 10 | | | | | | | 2.231 | 2.231 |
| | 4 | | | | | | | | 2.223 | 2.223 |
| 803 | 1 | 1 | 0.1 | ±18.5 | 6.081 | >100 | 5.554 | >100 | 0.2001 | 0.19976 |
| | 2 | | | | | | | | 0.2002 | 0.1993 |
| | 3 | 10 | | | | | | | 2.231 | 13 |
| | 4 | | | | | | | | 2.223 | 2.221 |

NOTE:
1. Au (LET = 86MeV•$cm^2$/mg) was used to $5x10^6$ ion/$cm^2$ at a flux of $2.5x10^4$ ion/($cm^2$s) for each irradiation with $T_{CASE}$ = +125°C for each run.

TABLE 2. SUMMARY OF THE SET TESTING DONE ON THE ISL70219ASEH

| RUN | DUT | SPECIES AND ANGLE | EFFECTIVE LET MeV*cm$^2$/mg | GAIN SETTING | $V_{IN}$ (V) | $V_S$ (V) | ±20mV A+B CAPTURES | Events/ Fluence (cm$^2$) |
|---|---|---|---|---|---|---|---|---|
| 401 | 1 | Pr∠15° | 60.0 | 1 | 0 | ±2.25 | 3199 | 8.0E-04 |
| | 2 | | | | | | 3536 | 8.8E-04 |
| | 3 | | | 10 | | | 834 | 2.1E-04 |
| | 4 | | | | | | 1284 | 3.2E-04 |
| 402 | 1 | Pr∠15° | 60.0 | 1 | 0 | ±18 | 3700 | 9.3E-04 |
| | 2 | | | | | | 4461 | 1.1E-03 |
| | 3 | | | 10 | | | 1020 | 2.6E-04 |
| | 4 | | | | | | 1510 | 3.8E-04 |
| 301 | 1 | Kr∠0° | 28.0 | 1 | 0 | ±2.25 | 2703 | 6.8E-04 |
| | 2 | | | | | | 3113 | 7.8E-04 |
| | 3 | | | 10 | | | 1084 | 2.7E-04 |
| | 4 | | | | | | 2414 | 6.0E-04 |
| 302 | 1 | Kr∠0° | 28.0 | 1 | 0 | ±18 | 2986 | 7.5E-04 |
| | 2 | | | | | | 3593 | 9.0E-04 |
| | 3 | | | 10 | | | 1136 | 2.8E-04 |
| | 4 | | | | | | 2341 | 5.9E-04 |
| 201 | 1 | Ar∠0° | 8.5 | 1 | 0 | ±2.25 | 1758 | 4.4E-04 |
| | 2 | | | | | | 2625 | 6.6E-04 |
| | 3 | | | 10 | | | 1042 | 2.6E-04 |
| | 4 | | | | | | 2139 | 5.3E-04 |
| 202 | 1 | Ar∠0° | 8.5 | 1 | 0 | ±18 | 1820 | 7.5E-04 |
| | 2 | | | | | | 1953 | 9.0E-04 |
| | 3 | | | 10 | | | 1351 | 2.8E-04 |
| | 4 | | | | | | 2576 | 5.9E-04 |
| 101 | 1 | Ne∠0° | 8.5 | 1 | 0 | ±2.25 | 241 | 6.0E-05 |
| | 2 | | | | | | 954 | 2.4E-04 |
| | 3 | | | 10 | | | 440 | 1.1E-04 |
| | 4 | | | | | | 704 | 1.8E-04 |
| 102 | 1 | Ne∠0° | 8.5 | 1 | 0 | ±18 | 203 | 5.1E-05 |
| | 2 | | | | | | 780 | 2.0E-04 |
| | 3 | | | 10 | | | 371 | 9.3E-05 |
| | 4 | | | | | | 620 | 1.6E-04 |

NOTE:

2. Each irradiation was done to a fluence of $4x10^6$ ion/cm$^2$ at a flux of $2x10^4$ ion/(cm$^2$s). Irradiation was done in the sequence from high LET to lowest and the same four devices were used throughout the testing. Testing was done with units at ambient temperature, about +25°C.

Figure 3 shows a plot of the SET duration outside of the ±100mV limits versus the extreme deviation during that SET. This provides a quick way of categorizing the SET by magnitude and duration. All captured SET in Figure 3 had durations of less than 10µs outside of the ±100mV window centered on the nominal amplifier output. The deviations are constrained by the output saturation to the supply rails of ±2.25V, approximately ±1.25V. The SET's group into distinct types as shown in the plot. The longest appear in the upper center of Figure 3 and have extreme deviations in the -200mV range and durations of approximately 7µs outside the ±100mV window. This particular SET type of SET (19 out of 1875 in $4x10^6$ ions/cm$^2$) is plotted as a composite SET plot in Figure 4. Although the time outside the ±100mV window was approximately 7µs, the composite plot indicates the total SET durations were actually out to about 10µs before the nominal output was restored.

Figure 5 is a composite plot of the 30 next largest durations SET captured for the test represented in Figure 3. These appear at the upper left of Figure 3 and all represent negative extreme deviations. The deviations of these events go essentially rail-to-rail and the total durations of these events are all under 7µs total.

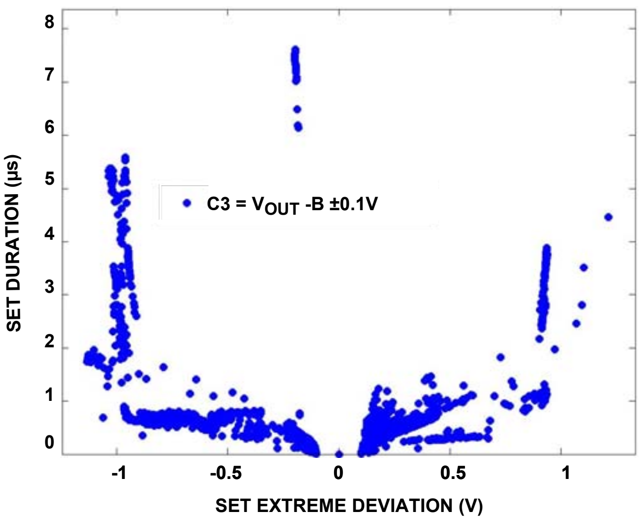


FIGURE 3. DUT1/SCOPE1 CHANNEL B RUN 401 (G = 1, $V_S$ = ±2.25V, LET = 60) SET OF LARGER THAN ±100mV (1875 IN $4x10^6$ IONS/cm$^2$) PLOTTED BY EXTREME DEVIATION ON THE ABSCISSA AND BY TOTAL DURATION OUTSIDE OF ±100mV ON THE ORDINATE

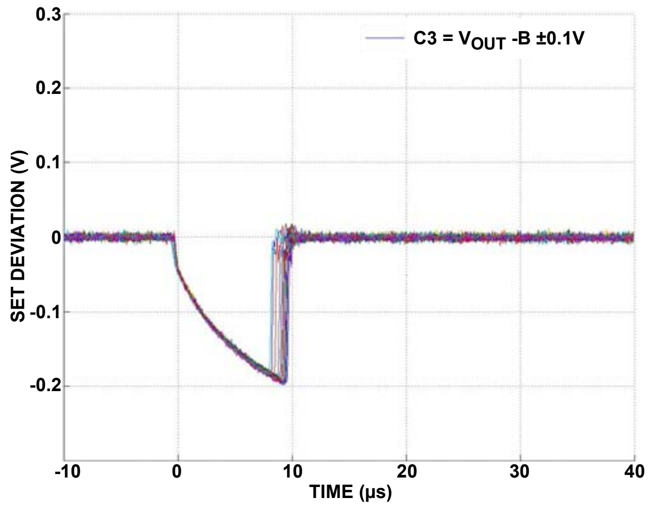


FIGURE 4. COMPOSITE SET PLOTS FOR THE 19 SET IN UPPER CENTER OF Figure 3 OF DUT1/SCOPE1 CHANNEL B RUN 401 (G = 1, $V_S$ = ±2.25, LET = 60)

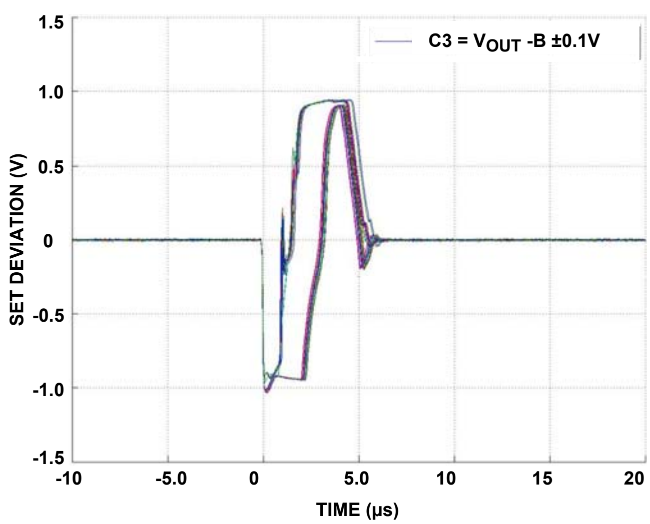


FIGURE 5. THE 30 LONGEST SET FOR DUT1/SCOPE1 CHANNEL B RUN 401 (G = 1, $V_S$ = ±2.25, LET = 60) AFTER THOSE REPRESENTED IN Figure 4

The next interesting grouping is the positive deviations in the middle right of Figure 3. The 30 longest SET of this grouping are plotted in Figure 6. Again the total deviation from the composite plot of Figure 5 is always less than for approximately 7µs.

When the supply rails are taken to ±18V, the SET are no longer constrained in deviation and exhibit a somewhat different pattern on the deviation versus duration plot as in Figure 7. The central grouping at about 6µs is no longer the longest SET type. A composite of the 30 longest SET events is shown in Figure 8. All of these events begin with a step discontinuity that may be either positive or negative, but then all the SET take on a positive deviation for the bulk of the duration. A single event persists for 15µs while the other 29 events are over within 12µs.

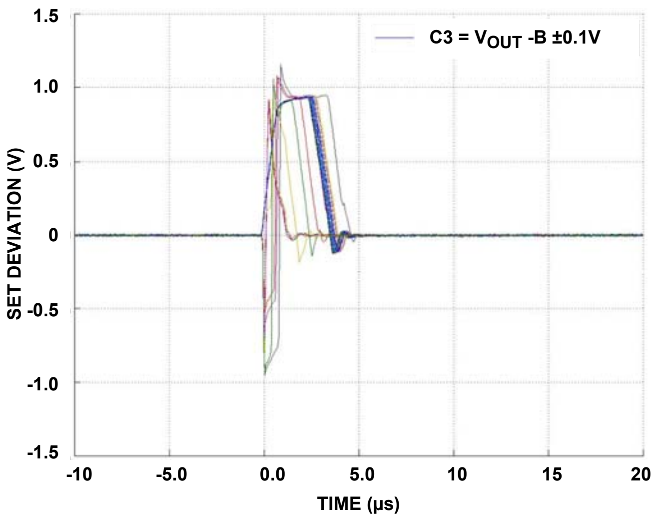


**FIGURE 6. THE 30 LONGEST LARGE POSITIVE EXTREME DEVIATION SET (UPPER RIGHT OF Figure 2) FOR DUT1/SCOPE1 CHANNEL B RUN 401, (G = 1, $V_S$ =±2.25, LET = 60)**

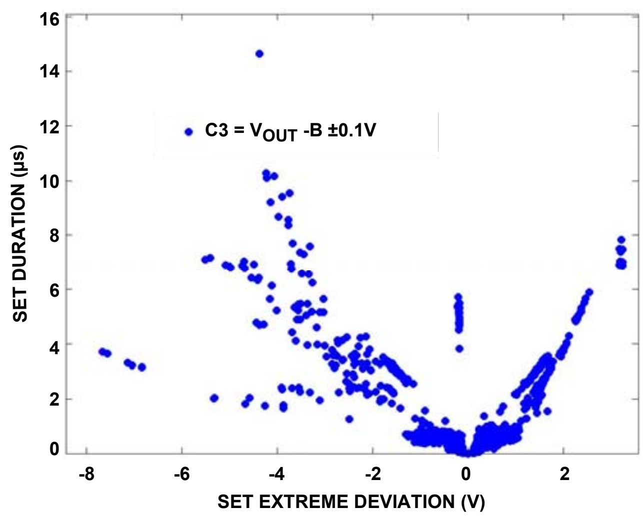


**FIGURE 7. DUT1/SCOPE1 CHANNEL B RUN 402 (G = 1, LET = 60, $V_S$ = ±18V) SET OF LARGER THAN ±100mV (2140 IN 4x10$^6$ IONS/cm$^2$) PLOTTED BY EXTREME DEVIATION ON THE ABSCISSA AND BY TOTAL DURATION OUTSIDE OF ±100mV ON THE ORDINATE**

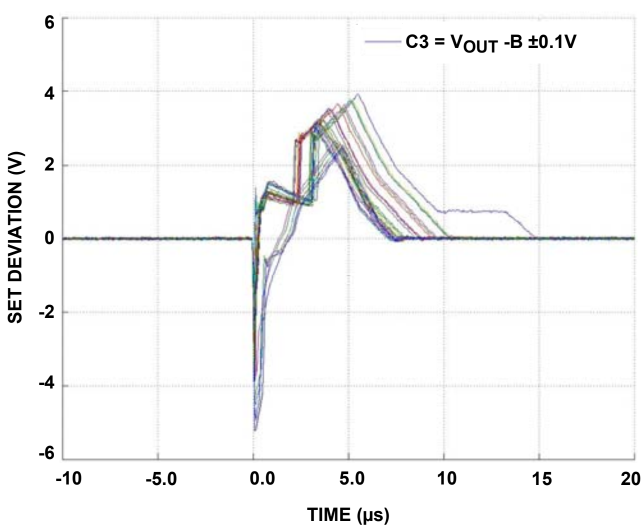


**FIGURE 8. COMPOSITE TRACE PLOT OF THE 30 LONGEST DURATION EVENTS OUTSIDE OF ±100mV FOR DUT1/SCOPE1 RUN 402 (G = 1, $V_S$ = ±18V, LET = 60)**

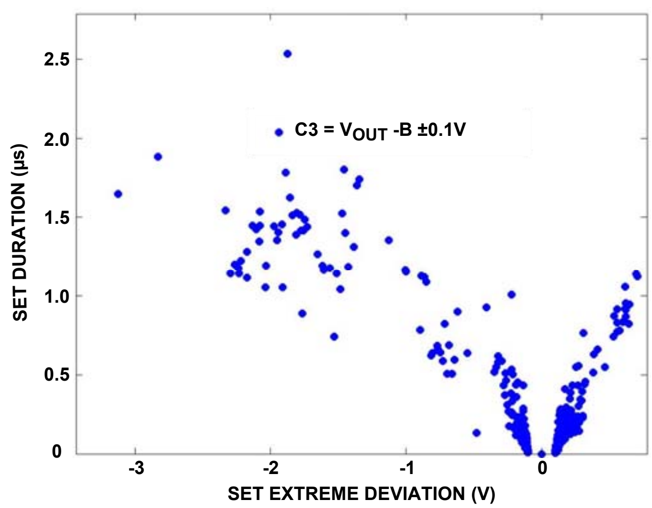


**FIGURE 9. DUT1/SCOPE1 CHANNEL B RUN 202 (G = 1, LET = 8.5, $V_S$ = ±18V) PLOT OF SET OUTSIDE OF ±100mV DEVIATION**

Dropping the LET results in smaller and shorter SET as is indicated in Figure 9 where the SET are resulting from LET = 8.5 Ar ions. The 30 longest SET of those in Figure 9 are plotted in Figure 10. These all start with a negative spike and then rebound for a positive triangle, and all of over within 3µs.

Dropping to LET = 2.7 (Ne) further reduces the SET in both deviation and duration as depicted in Figure 11. These SET are little more than spikes and are shown in Figure 12.

Changing the amplifier gain from 1 to 10 has minor impact on the SET forms as can be seen in Figure 13 as compared to Figure 7. Again the SET durations beyond ±100mV are below 10µs while the deviations can go past -6V. The 30 longest SET are depicted in Figure 14 and again exhibit an initial negative step with less than a µs duration followed by a positive deviation that can extend to almost 10µs. These SET are similar to those in Figure 8, which differ only in the gain configuration.

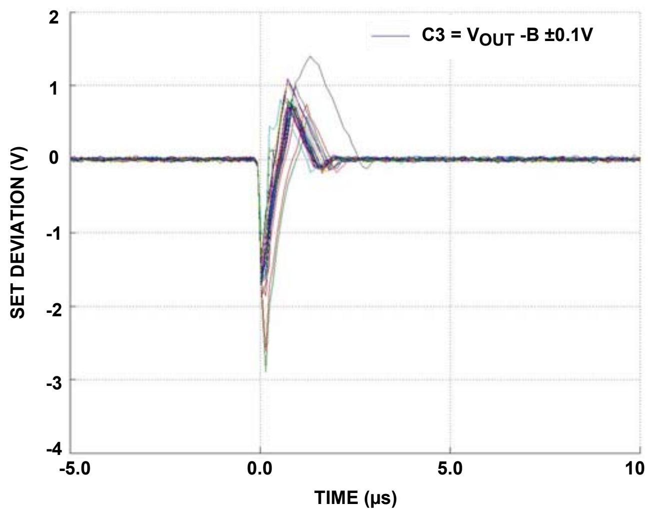


FIGURE 10. 30 LONGEST EVENTS RECORDED FOR DUT1/SCOPE1 RUN 202 (LET = 8.5, $V_S$ = ±18V)

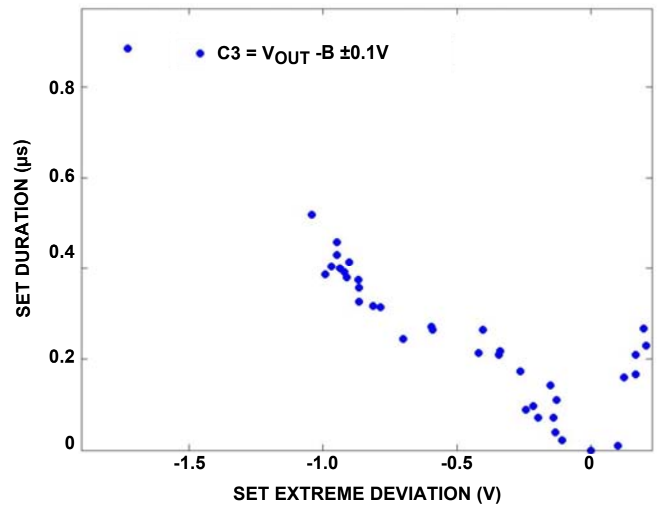


FIGURE 11. DUT1/SCOPE1 CHANNEL B RUN 102 (G = 1, $V_S$ = ±18V, LET = 2.7) EVENTS BEYOND ±100mV (37 in $4x10^6$ IONS/cm2)

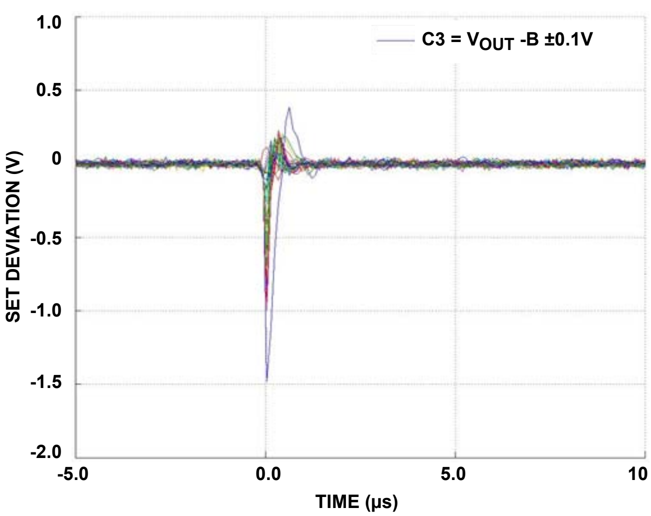


FIGURE 12. COMPOSITE OF THE 37 SET OUTSIDE ±100mV FROM DUT1/SCOPE1 RUN 102 (G = 1, $V_S$ = ±18V, LET = 2.7)

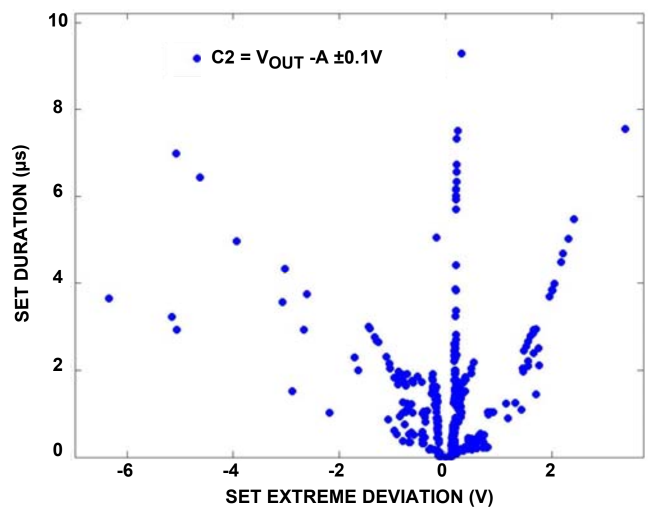


FIGURE 13. DUT3/SCOPE3 CHANNEL A RUN 402 (G = 10, LET = 60, $V_S$ = ±18V) FOR SET BEYOND THE ±100mV THRESHOLD (478 IN $4x10^6$ IONS/$cm^2$)

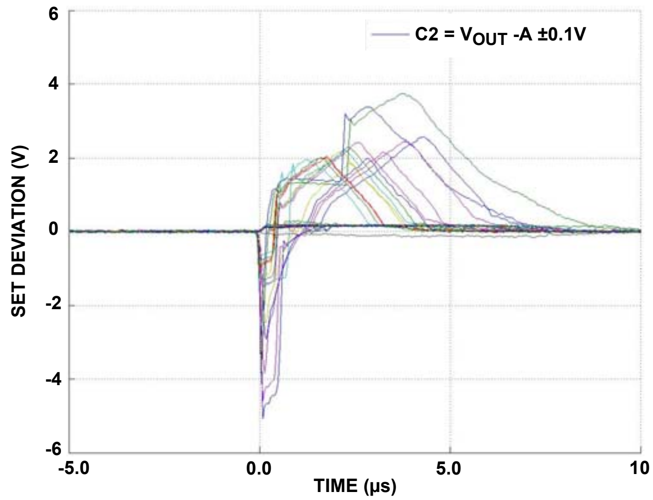


FIGURE 14. The 30 LONGEST SET TO ±100mv FOR DUT3/SCOPE3 CHANNEL A RUN 402 (G = 10, $V_S$ = ±18, LET = 60)

## Conclusions

The ISL70219ASEH dual operational amplifier has been shown to be free of permanent damage under irradiation by ions with LET of 86 MeV•mc$^2$/mg (normal incidence) up to supply voltages of ±18V at +125ºC case temperature. Permanent damage was observed at supply voltages of ±18.5V.

SET testing at +25°C demonstrated that SET resulting from ions of up to effective LET = 60 are limited to 15µs in duration. The deviation for these SET, range from -8V to +4V from a nominal 0V output at supply rails of ±18V. These magnitudes as well as the durations, decrease with decreasing LET. At LET = 2.7 SET are bounded between -2V and +1V and have durations of less than 2µs. The ±100mV SET cross section per device at LET = 2.7 has a lower bound of approximately 3x10$^{-5}$ cm$^2$.

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