ISL70218SRH

SEE Test Report

AN1677
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Introduction

The intense heavy ion environment encountered in space applications can cause transient and destructive effects in analog circuits including Single Event Latch-Up (SEL), Single Event Transients (SET), and Single Event Burnout (SEB). Transient and destructive effects can lead to system-level failures including disruption and permanent damage. For a predictable and reliable system operation, system components have to be formally designed and fabricated for SEE hardness and followed by a detailed SEE testing to validate the design. This report discusses the results of SEE testing of the Renesas ISL70218SRH.

Related Literature

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

- ISL70218SRH product page

Product Description

The ISL70218SRH is a dual, low-power precision amplifier optimized for single-supply applications. The operational amplifier (op amp) features a common-mode input voltage range extending to 0.5V below the V- rail, a rail-to-rail differential input voltage range, and a rail-to-rail output voltage swing. This makes it ideal for single-supply applications where input operation at ground is important.

The ISL70218SRH is implemented in an advanced bonded wafer SOI process using a deep trench isolation that results in a fully isolated structure. The SOI process technology also results in latch-up free performance, whether electrically or Single Event (SEL) caused.

This amplifier operates over a single supply range of 3V to 36V or a split supply voltage range of +1.8V/-1.2V to ±18V. The combination of precision and small footprint provides the user with outstanding value and flexibility relative to similar competitive parts.
Applications for these amplifiers include precision active filters, low noise front ends, loop filters, and data acquisition and charge amplifiers. The part is packaged in a 10 Ld hermetic ceramic flat pack and operates across the extended temperature range of -55°C to +125°C. A summary of key full temperature range specifications follows:

- Input Offset Voltage . . . . 290µV, max.
- Offset Voltage Drift . . . . 1µV/°C, max.
- Input Offset Current . . . . 75nA, max.
- Input Bias Current . . . . 800nA, max.
- Supply Current/Amplifier . . . . 1.4mA, max.
- Gain Bandwidth Product . . . . 4MHz, typ.

SEE Test Objective

The objectives of SEE testing on the ISL70218SRH were to evaluate its susceptibility to SEL and SEB and characterize its SET behavior over various LET levels.

SEE Test Facility

Testing was performed at the Texas A&M University (TAMU) Cyclotron Institute heavy ion facility. The facility is coupled to a K500 super-conducting cyclotron that 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 Procedure

The part was tested for single event latch-up and burnout using Au ions (LET = 86.4MeV/mg/cm^2) and single event transient using Ne, Ar, and Kr ions.

The Device Under Test (DUT) was mounted in the beam line and irradiated with heavy ions of the appropriate species. The parts were assembled in 10 lead dual in-line packages with the metal lid removed for beam exposure. The beam was directed onto the exposed die, and the beam flux, beam fluence, and errors in the device outputs were measured.

The tests were controlled remotely from the control room. All input power was supplied from portable power supplies connected using cable to the DUT. The supply currents were monitored along with the device outputs. All currents were measured with digital ammeters, while all the output waveforms were monitored on a digital oscilloscope for ease of identifying the different types of SEE, which the part displayed. Events were captured by triggering on changes in the output.

SEE Test Set-Up Diagrams

A schematic of the evaluation board is shown in Figure 1.

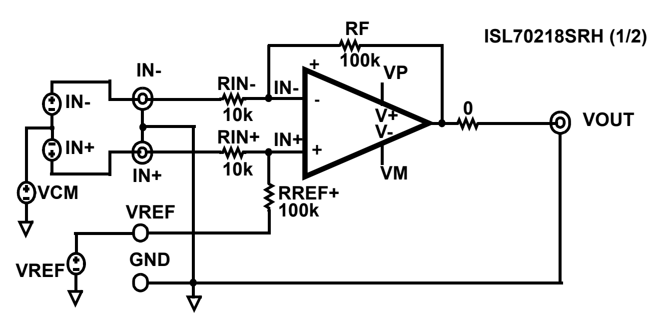

FIGURE 1. SIMPLIFIED SEE SCHEMATIC

Each operational amplifier was set up in a non-inverting operation with G = 11V/V. The IN- inputs were grounded and the input signal was applied to the IN+ pin.

Cross-Section Calculation

Cross sections are calculated using Equation 1:

$$CS(LET) = N/F \quad \text{(EQ. 1)}$$

where:

- CS is the SET cross section (cm^2) expressed as a function of the heavy ion LET
- LET is the linear energy transfer in MeV•cm^2/mg corrected according to the incident angle, if any.
- N is the total number of SET events
- F is fluence in particles/cm^2 corrected according to the incident angle, if any.

A value of 1/F is the assumed cross section when no event is observed.

Single Event Latch-Up and Burnout Results

The first testing sequence looked at the destructive effects due to burnout or latch-up. A burnout condition is indicated by a permanent change in the device supply current after application of the beam. If the increased current is reset by cycling power, it is termed a latch-up. No burnout or latch-up was observed using Au ions (LET = 86.4MeV•cm^2/mg) at 0° incidence from the perpendicular. Testing was performed on four parts at +125°C (case temperature) and up to the maximum voltage, V_S = ±18.2V. The first two parts (part ID 1 and 2) commenced testing with V_S = ±15V and on subsequent tests V_S voltage was increased to ±17.5V and then ±18.2V. All other parts were tested with a V_S of ±17.5V and ±18.2V. All test runs were run to a fluence of $2x10^6/cm^2$. A power supply applied a DC voltage of 200mV to the non-inverting inputs of the amplifiers during the test. Functionality of all outputs was verified after exposure. I_{DD} and I_{EE} were recorded pre and post exposure, with 5% resolution. Results are shown in Table 1 for the 36.4V total supply voltage.

Single Event Transient Testing

Test Method

Biasing used for SET test runs was V_S = ±4.5V and ±18V. Similar to SEL/B testing, a DC voltage of 200mV was applied to the non-inverting inputs of the amplifiers. Signals from the switch board in the control room were connected to two LECROY oscilloscopes: one was set to capture transients due to the output of channel A, and the other was set to capture transients on the output of channel B.

SET events are recorded when movement on output during beam exposure exceeds the set window trigger of ±80mV. Summary of the scope settings are as follows:

- Scope 1 is set to trigger on Channel 1 to a OUTA window of ±80mV. Measurements on Scope 1 are:
  CH1 = OUTA 200mV/div, CH2 = OUTA 500mV/div,
  CH3 = OUTB 200mV/div, CH4 = OUT5 500mV/div.
- Scope 2 is set to trigger on Channel 3 to a OUTB window of ±80mV. Measurements on Scope 2 are:
  CH1 = OUTA 200mV/div, CH2 = OUTA 500mV/div,
  CH3 = OUTB 200mV/div, CH4 = OUT5 500mV/div.

The switch board at the end of the 20-ft cabling was found to require terminations of 10nF to keep the noise on the waveforms to a minimum.

Cross Section Results

Compared to other Renesas radiation tolerant circuits, the ISL70218SRH was not designed for SET mitigation. The best approach to characterize the single event transient response is to represent the data on an LET threshold plot.

Figure 2 on page 3 shows the cross section of the IC versus the LET level at V_S = ±4.5V and ± 18V. For an LET < 20MeV•cm^2/mg, the cross section is nearly the same independent of supply voltage. As the linear energy transfer increases, there is noticeable increases in the cross section area with a higher supply voltage. Data from Figure 2 is represented in Table 2 on page 3.

Figures 3 through 6 show the cross section of each channel independently at V_S = ±4.5V and ±18V with confidence interval bars for a 90% confidence level.

TABLE 1. ISL70218SRH DETAILS OF SEB/L TESTS FOR VS = ±18.2V and LET = 86.4MeV · cm^2/mg

TEMP (°C)	LET (MeV.•m^2/mg)	SUPPLY CURRENT PRE-EXPOSURE (mA)	SUPPLY CURRENT POST-EXPOSURE (mA)	LATCH EVENTS	CUMULATIVE FLUENCE (PARTICLES/cm^2)	CUMULATIVE CROSS SECTION (cm^2)	DEVICE	SEB/L
+125	86	3.8	3.7	0	2.0×10^6	5.0×10^{-7}	1	PASS
+125	86	3.8	3.8	0	2.0×10^6	5.0×10^{-7}	2	PASS
+125	86	4.0	3.9	0	2.0×10^6	5.0×10^{-7}	3	PASS
+125	86	3.8	3.7	0	2.0×10^6	5.0×10^{-7}	4	PASS
			TOTAL EVENTS	0				
				OVERALL FLUENCE	8.0×10^6			
					OVERALL CS	1.25×10^{-7}		
						TOTAL UNITS	4	

TABLE 2. DETAILS OF THE CROSS SECTION OF THE ISL70218SRH vs LET vs SUPPLY VOLTAGE

SUPPLY VOLTAGE (V)	ION	ANGLE (°)	EFF LET (cm^2/mg)	FLUENCE PER RUN ($PARTICLES/cm^2$)	NUMBER OF RUNS	TOTAL EVENTS	EVENT CS cm^2
±4.5V	Ne	0	2.7	2.0×10^6	4	13	1.63×10^{-6}
±4.5V	Ar	0	8	2.0×10^6	3	53	8.83×10^{-6}
±4.5V	Ar	60	17	2.0×10^6	4	391	4.89×10^{-5}
±4.5V	Kr	0	28	2.0×10^6	4	1097	1.37×10^{-4}
±4.5V	Kr	60	56	2.0×10^6	4	1579	1.97×10^{-4}
±18V	Ne	0	2.7	2.0×10^6	4	25	3.13×10^{-6}
±18V	Ne	60	5.4	2.0×10^6	4	148	1.85×10^{-6}
±18V	Ar	0	8	2.0×10^6	4	123	1.54×10^{-6}
±18V	Ar	60	17	2.0×10^6	4	390	4.88×10^{-5}
±18V	Kr	0	28	2.0×10^6	4	1655	2.07×10^{-4}
±18V	Kr	60	56	2.0×10^6	4	3410	4.26×10^{-4}

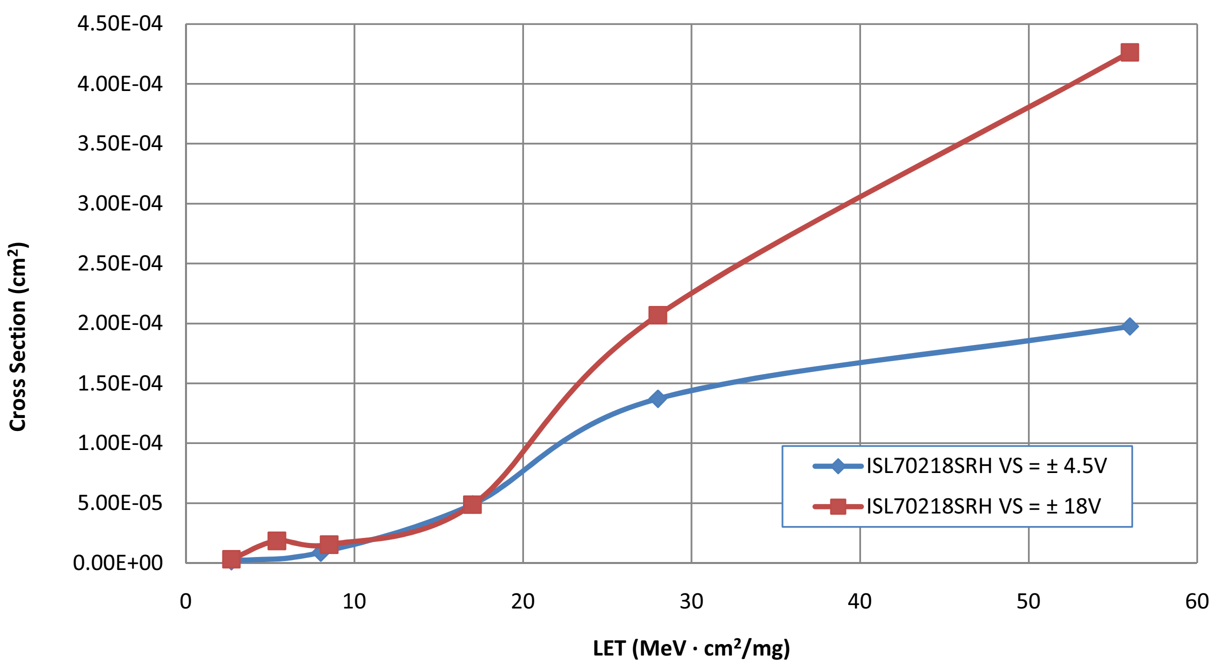

FIGURE 2. CROSS SECTION OF THE ISL70218SRH vs LINEAR ENERGY TRANSFER VS. SUPPLY VOLTAGE

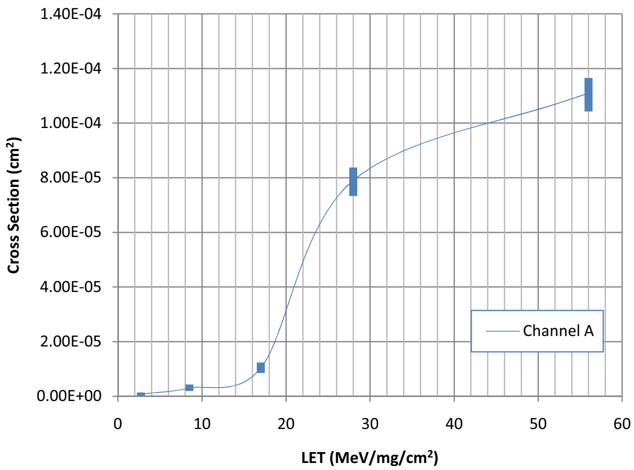

FIGURE 3. CHANNEL A CROSS SECTION VS. LET FOR V_S = ±4.5V WITH 90% CONFIDENCE LEVEL INTERVAL BARS

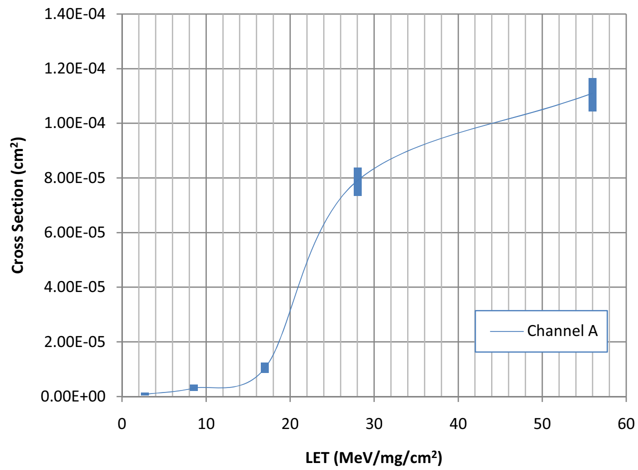

FIGURE 4. CHANNEL B CROSS SECTION VS. LET FOR V_S = ±4.5V WITH 90% CONFIDENCE LEVEL INTERVAL BARS

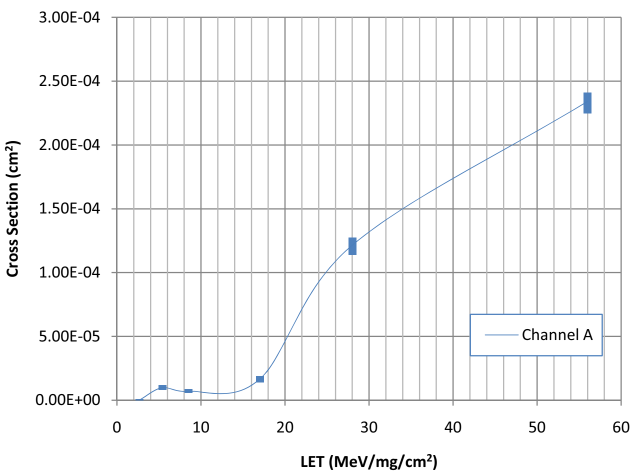

FIGURE 5. CHANNEL A CROSS SECTION VS. LET FOR V_S = ±18V WITH 90% CONFIDENCE LEVEL INTERVAL BARS

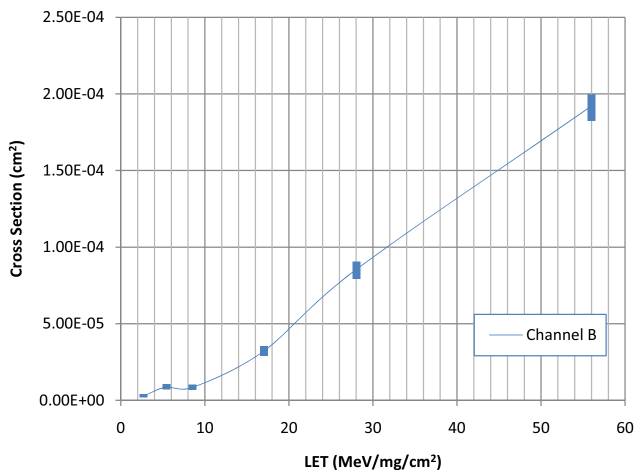

FIGURE 6. CHANNEL B CROSS SECTION VS. LET FOR V_S = ±18V WITH 90% CONFIDENCE LEVEL INTERVAL BARS

Transient Response

The ISL70218SRH features rail-to-rail output, so it was expected SETs would cause the output to rail out. Surprisingly, the majority of the transients were less than 10% of output voltage. Duration of the transients range in the 10's of µs to 100's of µs. Figures 7 though 28 represent output waveforms of the amplifiers under test at various bias conditions and LET values. The plots are composites of the first 25 transients captured on the scope. This information is useful in quantifying the excursion of the output as a result of SEE induced transients. The worst voltage transient seen is a 300mV excursion, and the longest SET duration is 1.6ms (see Figure 19 on page 8).

Typical SET Captures

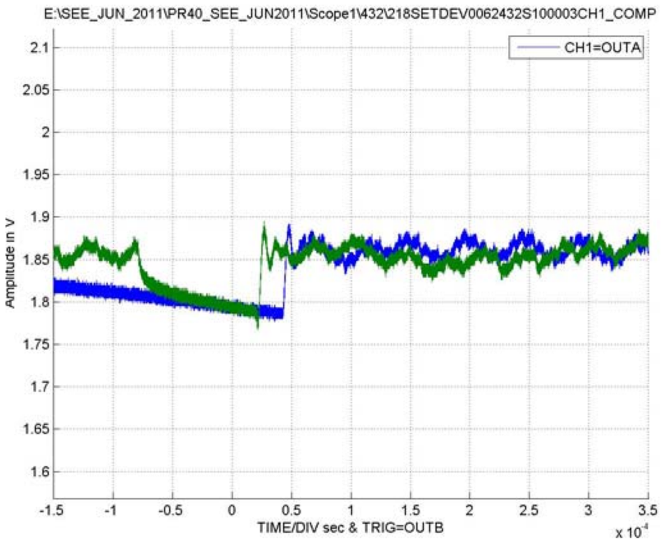

FIGURE 7. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL A, LET = 2.7MeV/mg/cm^2, RUN 432

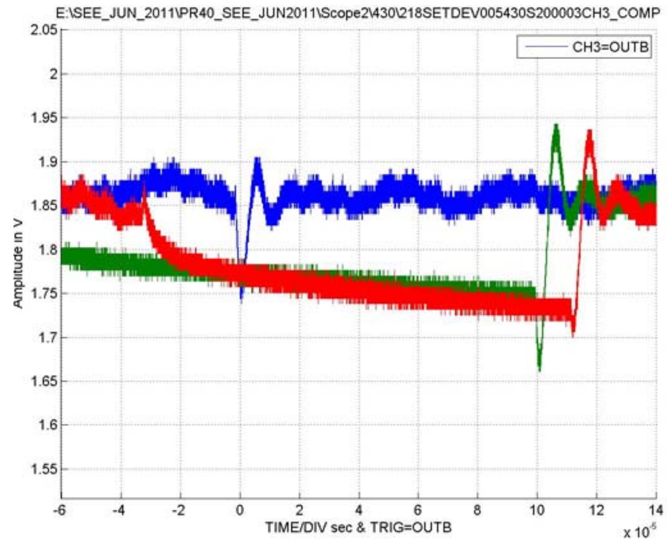

FIGURE 8. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL B, LET = 2.7MeV/mg/cm^2, RUN 430

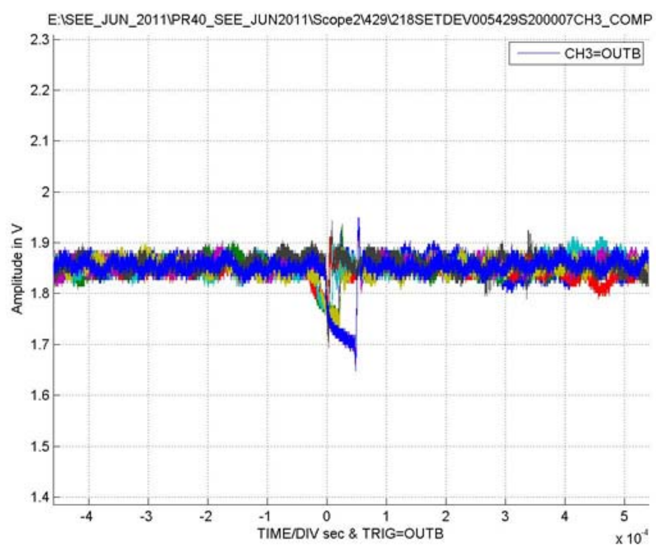

FIGURE 9. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL B, LET = 2.7MeV/mg/cm^2, RUN 429

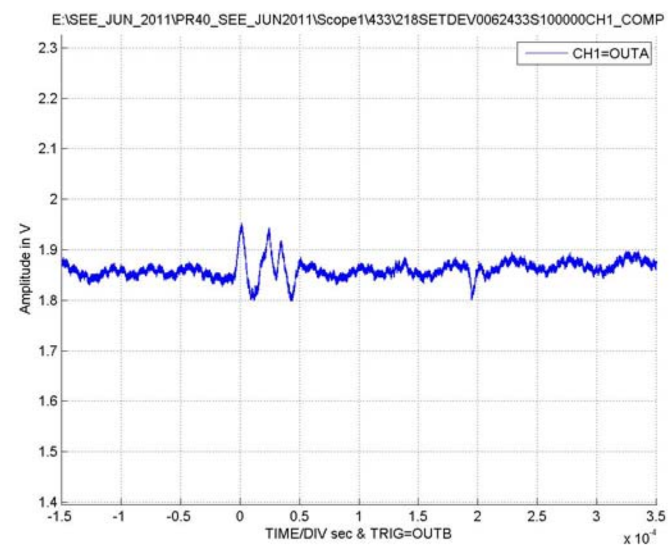

FIGURE 10. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL A, LET = 2.7MeV/mg/cm^2, RUN 433

Typical SET Captures (Continued)

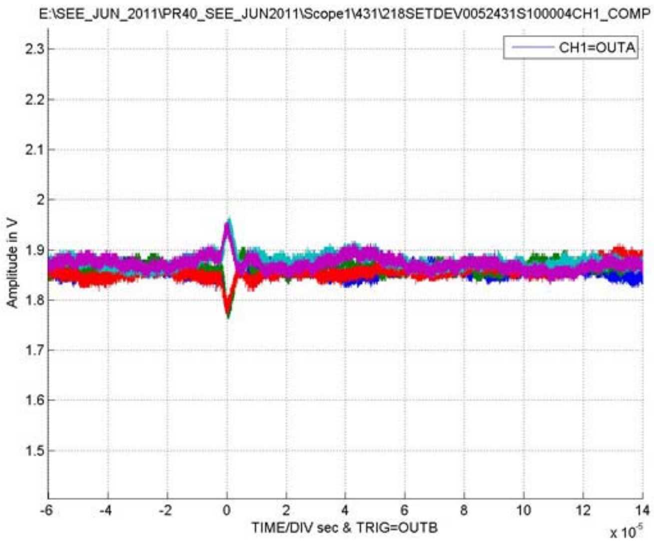

FIGURE 11. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL A, LET = 5.6MeV/mg/cm^2, RUN 431

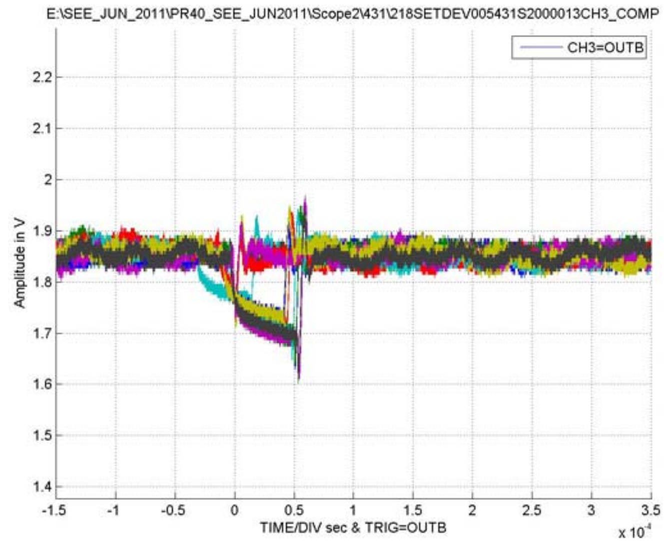

FIGURE 12. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL B, LET = 5.6MeV/mg/cm^2, RUN 432

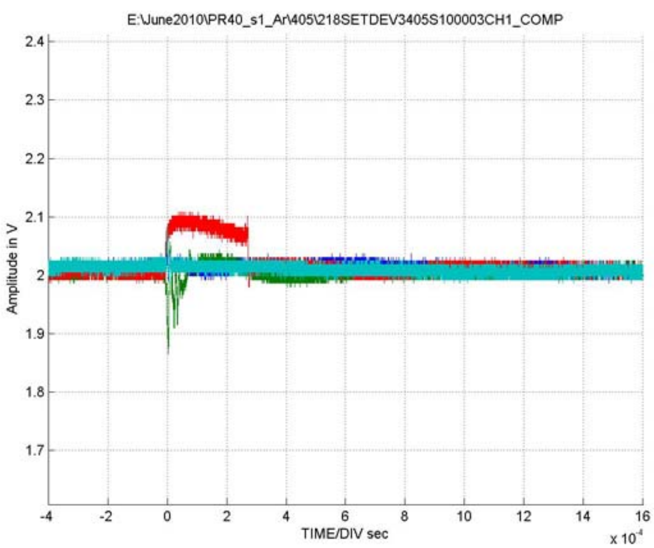

FIGURE 13. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL A, LET = 8.5MeV/mg/cm^2, RUN 405

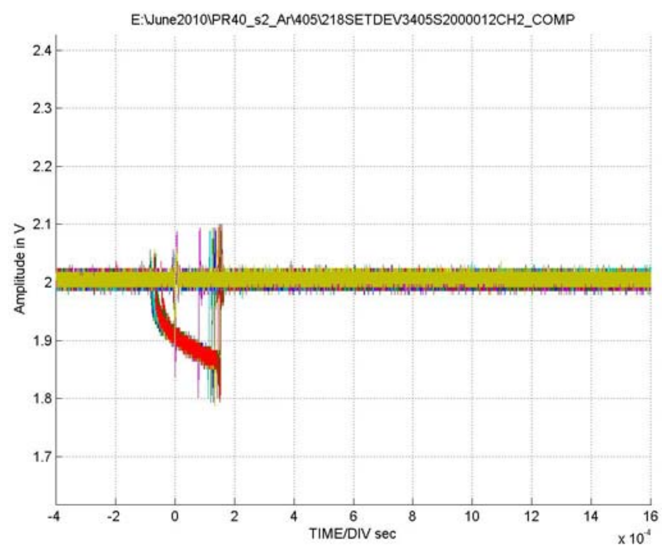

FIGURE 14. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL B, LET = 8.5MeV/mg/cm^2, RUN 405

Typical SET Captures (Continued)

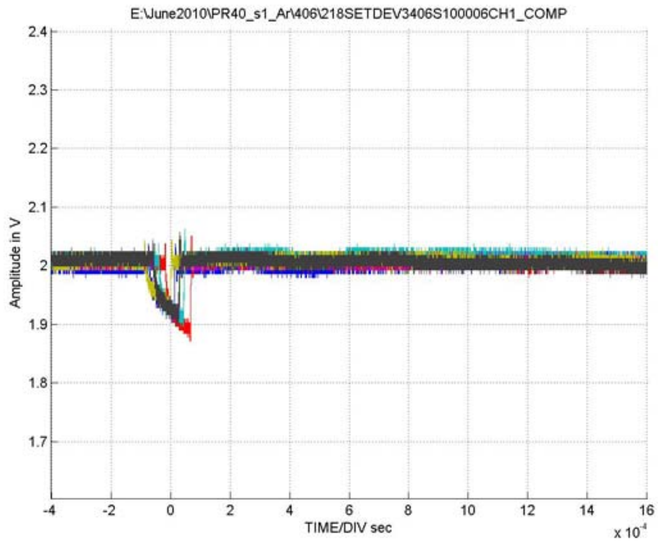

FIGURE 15. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL A, LET = 8.5MeV/mg/cm^2, RUN 406

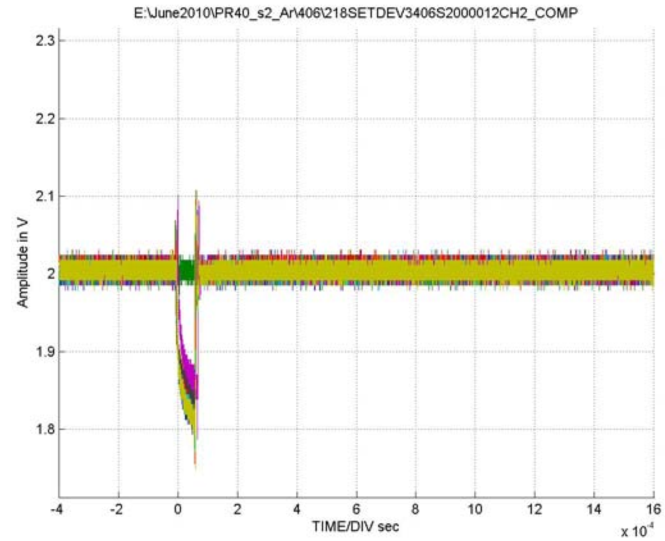

FIGURE 16. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL B, LET = 8.5MeV/mg/cm^2, RUN 406

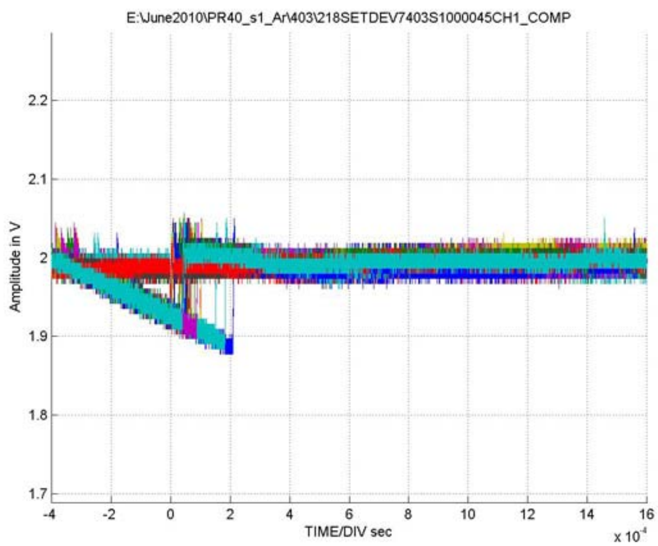

FIGURE 17. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL A, LET = 17MeV/mg/cm^2, RUN 403

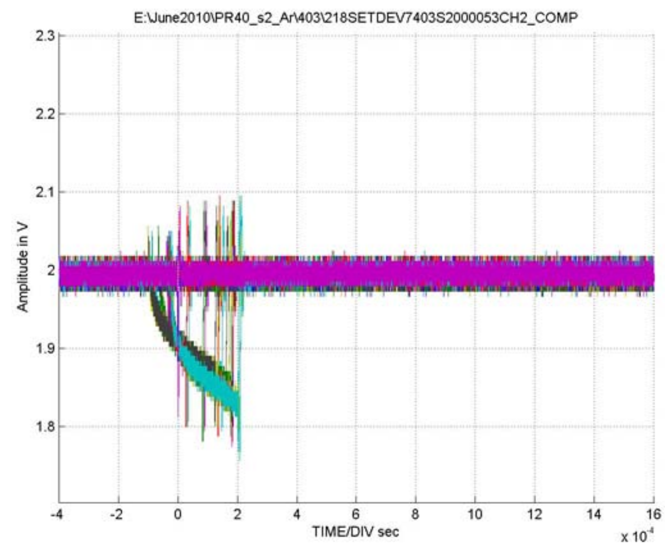

FIGURE 18. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL B, LET = 17MeV/mg/cm^2, RUN 403

Typical SET Captures (Continued)

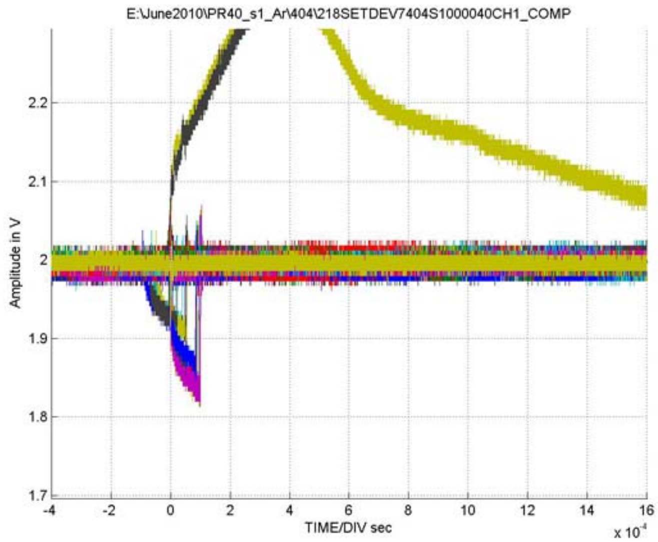

FIGURE 19. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL A, LET = 17MeV/mg/cm^2, RUN 404

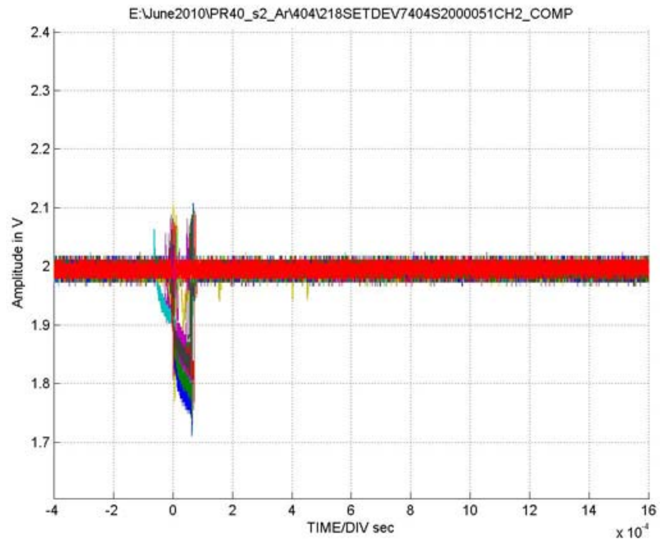

FIGURE 20. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL B, LET = 17MeV/mg/cm^2, RUN 404

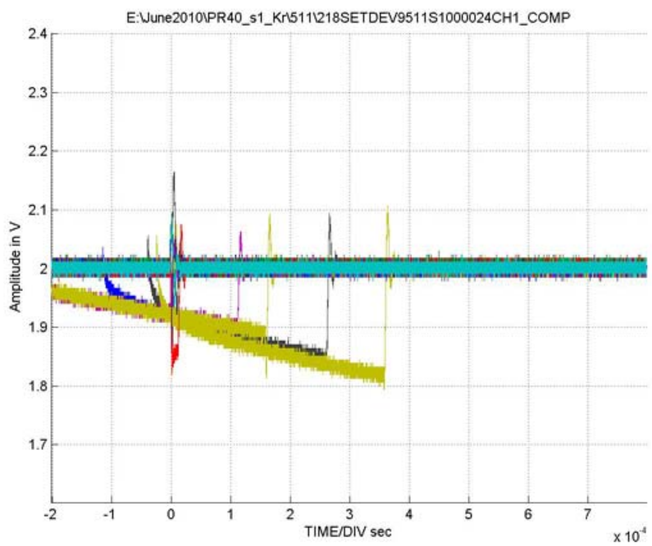

FIGURE 21. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL A, LET = 28MeV/mg/cm^2, RUN 511

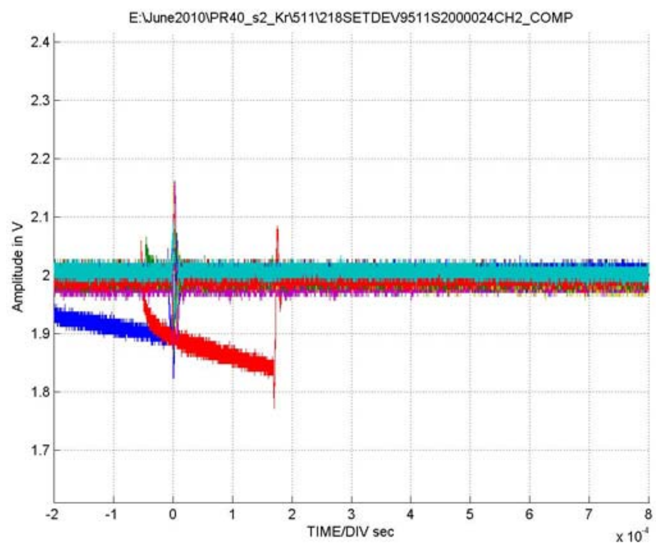

FIGURE 22. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL B, LET = 28MeV/mg/cm^2, RUN 511

Typical SET Captures (Continued)

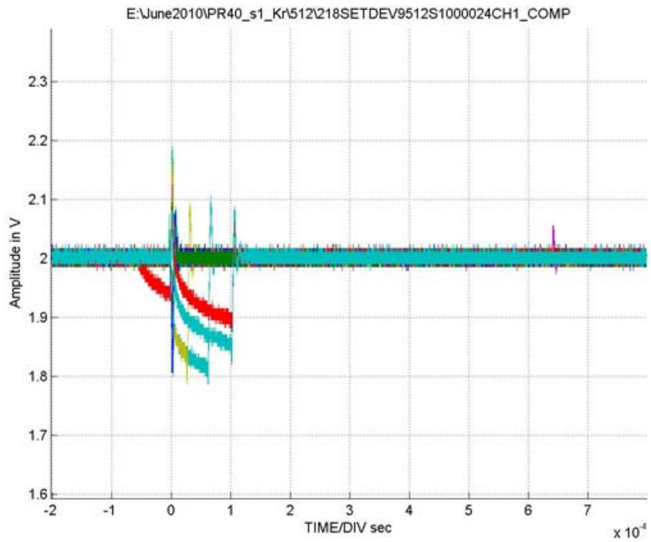

FIGURE 23. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL A, LET = 28MeV/mg/cm^2, RUN 512

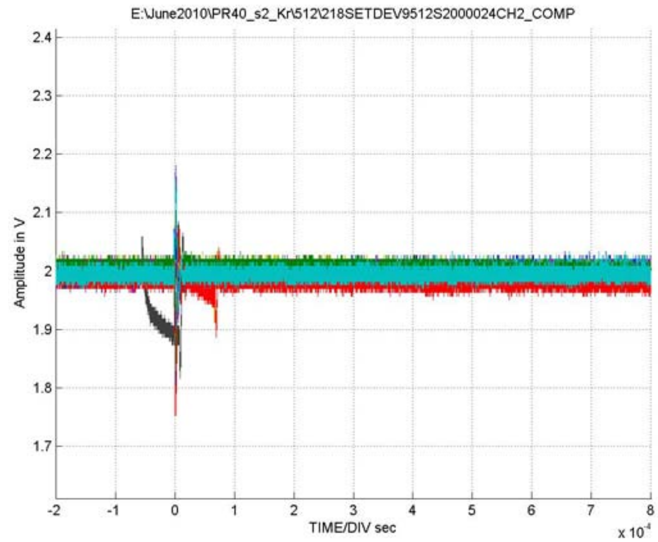

FIGURE 24. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL B, LET = 28MeV/mg/cm^2, RUN 512

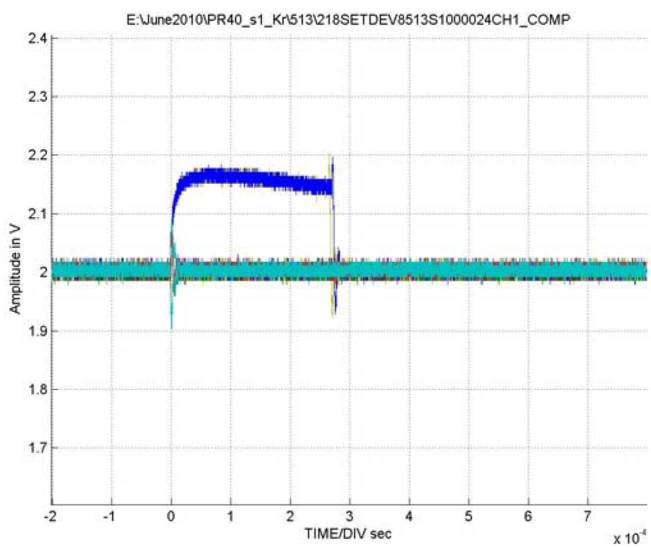

FIGURE 25. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL A, LET = 56MeV/mg/cm^2, RUN 513

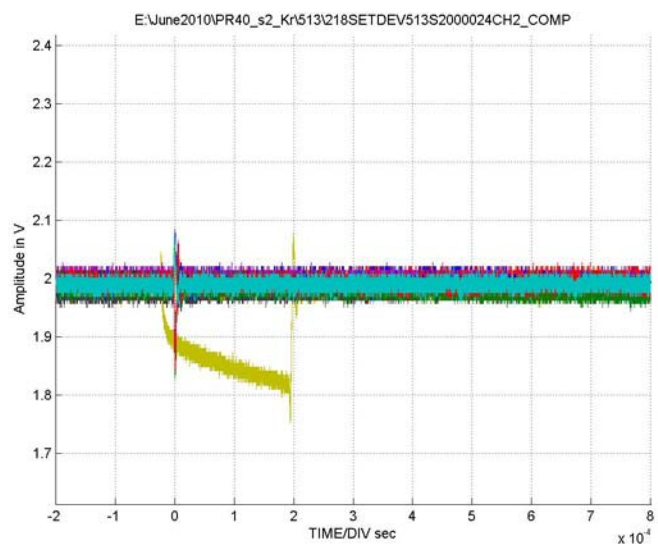

FIGURE 26. TYPICAL CAPTURE AT V_S = ±4.5V, CHANNEL B, LET = 56MeV/mg/cm^2, RUN 513

Typical SET Captures (Continued)

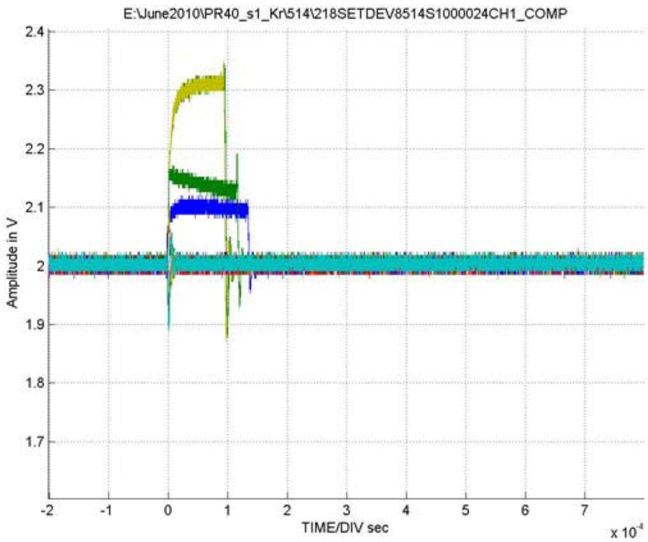

FIGURE 27. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL A, LET = 56MeV/mg/cm^2, RUN 514

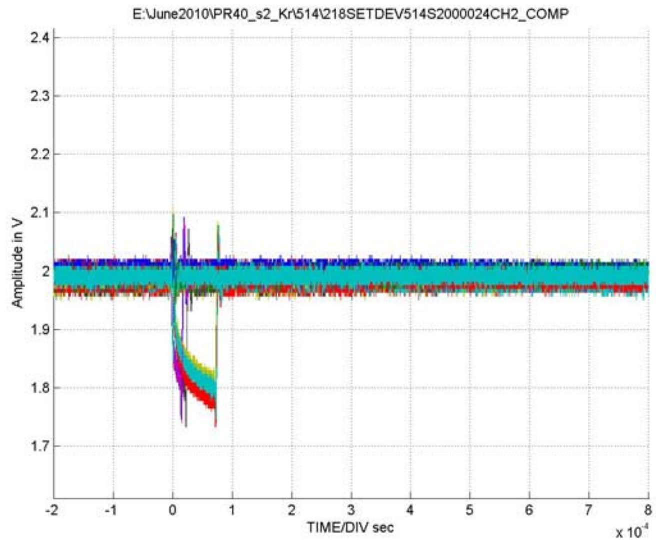

FIGURE 28. TYPICAL CAPTURE AT V_S = ±18V, CHANNEL B, LET = 56MeV/mg/cm^2, RUN 514

Summary

Single Event Burnout/Latch-up

No Single Event Burnout (SEB) was observed for the device up to an LET value of 86MeV•cm^2/mg (+125°C) and voltage supply of V_S = ± 18.2V. No single event latch-up (SEL) were observed for the device up to an LET value of 86MeV•cm^2/mg (+125°C). voltage supply of V_S = ± 18.2V.

Single Event Transient

Based on the results presented, the ISL70218SRH op amp offers advantages over the competitor’s part with respect to maximum SET output voltage excursion. No transient pulses > 0.5V were observed at LET levels up to 56MeV•cm^2/mg. Both the voltage level and duration of transients were proportional to LET. The maximum transients at an LET of 56MeV•cm^2/mg were observed to be ~300mV with a typical duration of > 200µs (see Figure 27). The longest transient duration observed was at an LET of 17MeV•cm^2/mg with an out of scale transient > 300mV, and the length of the transient was > 1.6ms.

Revision History

DATE	REVISION	CHANGE
Aug 10, 2018	1.00	Updated typos in the Summary section on page 10. Added Revision History section. Updated the disclaimer.

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