HS-OP470ARH, HS-OP470AEH

SEE Test Report

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 HS-OP470ARH product. The report also applies to the HS-OP470AEH.

Product Description

The HS-OP470ARH and HS-OP470AEH (SMD 5962-98533) are radiation hardened, monolithic quad operational amplifiers that provide highly reliable performance in harsh radiation environments. Excellent noise characteristics coupled with a unique array of dynamic specifications make these amplifiers well-suited for a variety of satellite system applications. Dielectrically isolated, bipolar processing makes these devices immune to single event latch-up.

The HS-OP470ARH and HS-OP470AEH show almost no change in offset voltage after exposure to 100krad(Si) gamma radiation, with only a minor increase in current. Complementing these specifications is a post radiation open-loop gain in excess of 40kV/V.

These quad operational amplifiers are available in an industry standard pinout, allowing for immediate interchangeability with most other quad operational amplifiers.

Related Literature

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

- HS-OP470ARH, HS-OP470AEH device pages

14 Ld Flatpack
Top View

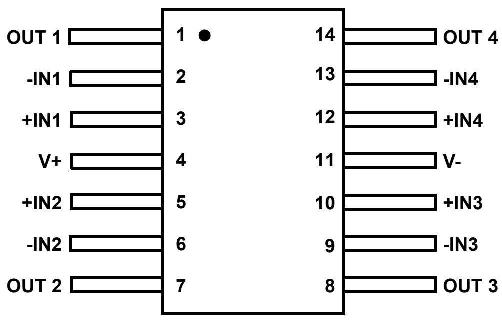

Figure 1. Pin Configuration for HS-OP470ARH and HS-OP470AEH

1. SEE Test Facility

The SEE testing was done at the Texas A&M University Cyclotron Institute. The K500 super conducting cyclotron can generate numerous beam species for a wide range of Linear Energy Transfer (LET) and ion flux. The testing described here was conducted on March 5, 2012.

2. SEE Test Configuration

The HS-OP470ARH units tested had the package lids removed to allow irradiation. The parts were configured as noninverting amplifiers with a gain of eleven. The feedback resistor was 100kΩ (between the outputs and the inverting inputs). Both inputs had 10kΩ resistors connected to them with the free end available for biasing. The output was unloaded except for the feedback resistor, the coaxial line going to the oscilloscopes, and voltage meters monitoring the outputs. For destructive SEE (SEB/L) testing, the inputs (both IN+ and IN-) were grounded. For SET testing, the resistors to the non-inverting inputs (IN+) were biased at 0.2V while the resistors to the inverting inputs were grounded so that the output was nominally 2.2V.

3. Single Event Burnout (SEB) Results

Four parts of the HS-OP470ARH were tested for destructive single event effects. Each of the four parts was irradiated while operating to $2x10^6$ion/cm^2 with normal incidence gold for a LET of 86MeV•cm^2/mg. The parts were heated to a case temperature of 125°C. Irradiations were done at supply voltages of ±16.5V, ±17.5V, and ±18.2V with inputs grounded through 10kΩ resistors and a gain of 11. The supply currents were measured both before and after irradiation to look for any changes. In the twelve irradiation cases (four parts and three voltages) the currents saw less than 1% changes indicating that no destructive events occurred.

4. Single Event Transient (SET) Results

For the SET testing, the non-inverting inputs were biased to 0.2V which set the outputs at approximately 2.2V. The outputs were monitored by oscilloscopes and a capture of the SET trace was triggered on ±80mV transients. Four units were tested at three different effective LET (2.5, 8.4, and 11.9MeV•cm^2/mg), and two of those units were tested at a higher LET of 28.3MeV•cm^2/mg. For the first three LET, an effective fluence of $2x10^6$ion/cm^2 was used while for the fourth LET the fluence was dropped to $5x10^5$ion/cm^2. The raw SET counts captured are presented in Table 1 and Table 2.

Table 1. ±80mV SET Trigger Counts for HS-OP470ARH Irradiated with Supply Voltages of ±5V

DUT	Species	Angle (Degrees)	Effective LET (MeV•cm^2/mg)	Fluence (ion/cm^2)	±80mV Event Count			
					CH1	CH2	CH3	CH4
5	Ne	0	2.5	$2x10^6$	72	86	75	99
6					67	136	132	117
7					76	129	108	78
8					73	142	107	98
5	Ar		8.4		395	491	558	769
6					450	549	661	583
7					437	518	570	561
8					415	485	585	588
5		45	11.9		899	845	1058	1055
6					802	947	1114	1018
7					789	832	1026	875
8					869	892	1040	950
7	Kr	0	28.3	$5x10^5$	389	459	481	465
8					339	473	447	445

Table 2. ±80mV SET Trigger Counts for HS-OP470ARH Irradiated with Supply Voltages of ±15V

DUT	Species	Angle (Degrees)	Effective LET ($MeV\bullet cm^2/mg$)	Fluence (ion/cm^2)	±80mV Event Count			
					CH1	CH2	CH3	CH4
5	Ne	0	2.5	$2x10^6$	145	182	167	204
6					113	137	228	211
7					172	242	204	192
8					168	164	212	221
5	Ar		8.4		614	683	794	851
6					601	642	845	732
7					644	492	823	781
8					574	720	828	854
5		45	11.9		1070	1096	1270	1274
6					972	1103	1274	1212
7					1127	1140	1284	1242
8					1070	1142	1273	1211
7	Kr	0	28.3	$5x10^5$	392	482	460	431
8					408	519	492	445

The question of whether there was a significant difference between the devices tested is addressed first. The event counts summed by Device Under Test (DUT) are presented in Figure 2. The total SET captured for all four channels over the first three LET varied by DUT from a low of 5999 for DUT7 to a high of 6576 for DUT6. The other two DUTs totaled 6402 (DUT5) and 6244 (DUT8). For the highest LET, the two devices DUT7 and DUT8 totaled 1794 and 1704, respectively. Therefore, the DUTs displayed very similar SET totals and so did not indicate any significant difference between the devices. The DUTs are so considered to be equally representative.

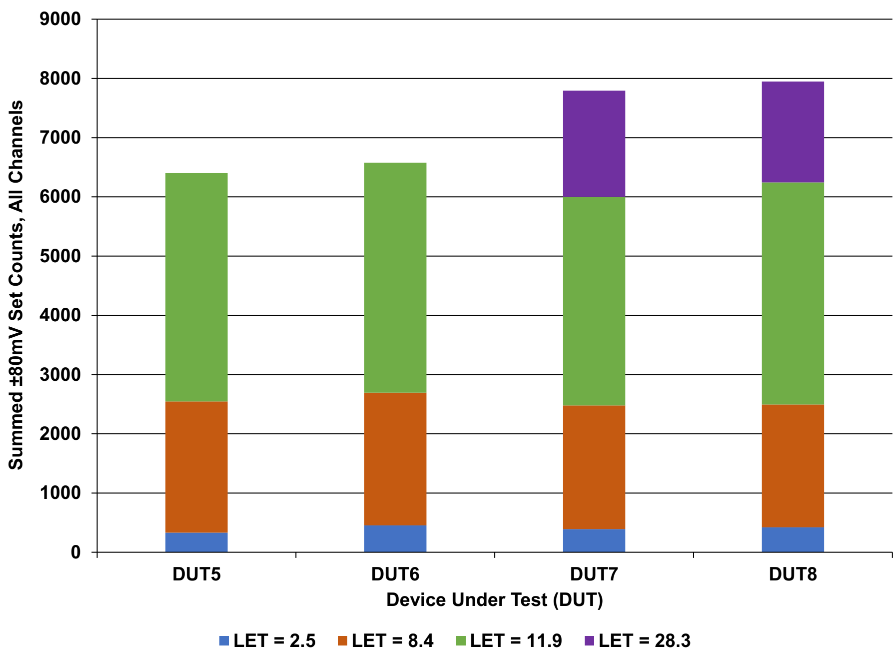

Figure 2. ±80mV SET Counts Summed for All Channels by DUT and Effective LET for Supplies of ±5V

The variation by channel is presented in Figure 3. Although there appears to be some variability by channel there does not appear to be a systematic variation by channel. Based on this, any channel is considered to be representative of all channels.

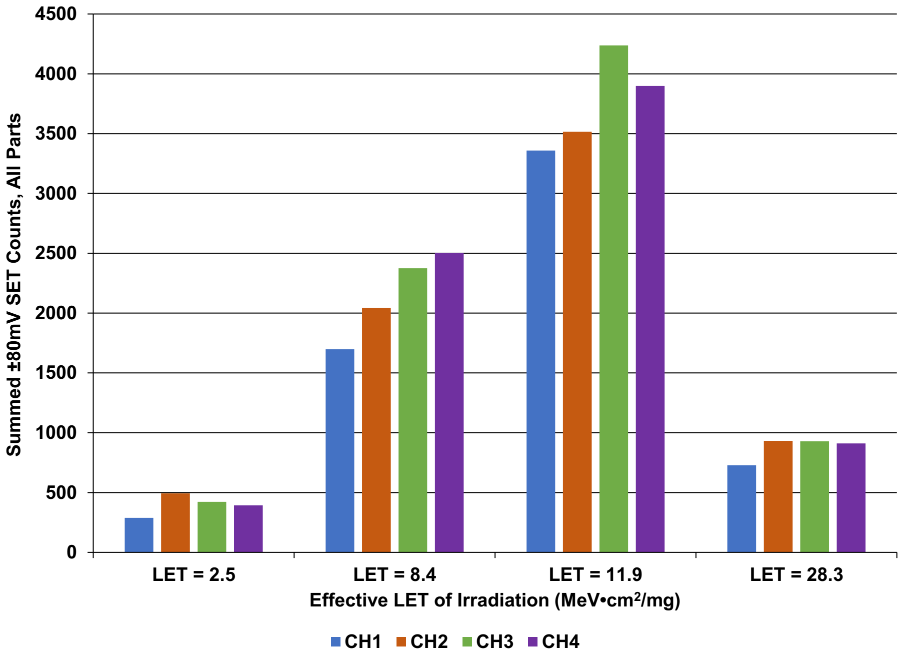

Figure 3. ±80mV SET Counts Summed Across all DUTs by Channel and Effective LET for Supplies of ±5V

The SET counts were converted to effective cross sections (events/fluence) and plotted in Figure 4. Each DUT and channel is represented by a plotted point, and the means at each LET are connected to give the lines. Summary statistics on the combined cross sections are in Table 3.

Table 3. Summary Cross Section Statistics Taken from the Population of Cross Sections for Each DUT and Channel

Effective LET (MeV•cm^2/mg)	Cross Sections (cm^2) Statistics at ±5V			Cross Sections (cm^2) Statistics at ±15V		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
2.5	3.35E-05	4.98E-05	7.10E-05	5.65E-05	9.26E-05	1.21E-04
8.4	1.98E-04	2.69E-04	3.85E-04	2.46E-04	3.59E-04	4.27E-04
11.9	3.95E-04	4.69E-04	5.57E-04	4.86E-04	5.86E-04	6.42E-04
28.3	6.78E-04	8.75E-04	9.62E-04	7.84E-04	9.07E-04	1.04E-03

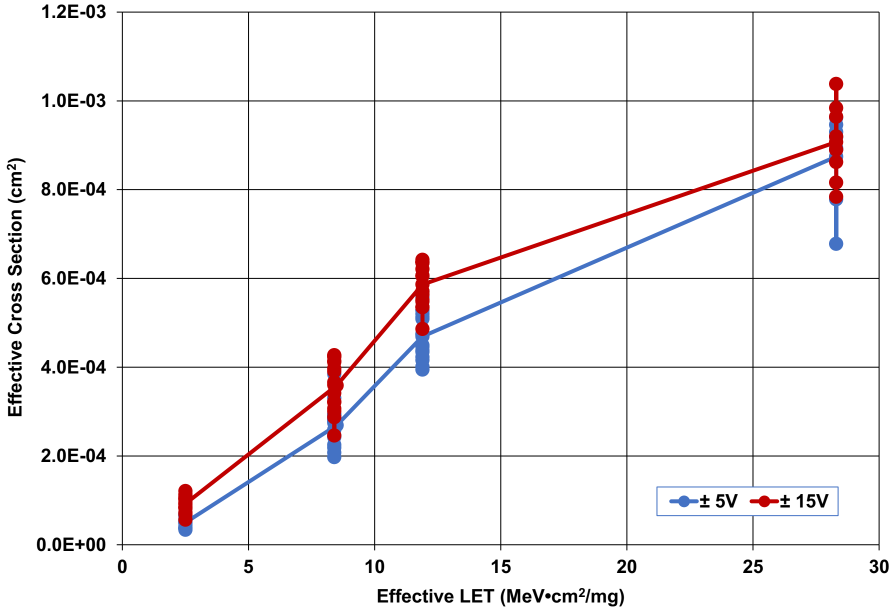

Figure 4. HS-OP470ARH ±80mV SET cross sections for all channels and all parts. Four parts are included for an effective LET of 2.5, 8.4, and 11.9MeV•cm^2/mg, but only two parts are included for LET = 28.3MeV•cm^2/mg. The lines connect the mean cross sections. The parts were configured as a non-inverting buffer with a gain of 11 and biased with an input of +0.2V.

Selected SET capture collections (for a DUT channel by LET) were submitted to a MATLAB routine to extract the extreme SET deviations and the duration outside of the ±80mV window on the nominal output. In addition to finding the SET extremes, the collection was sorted to select the SET with the twenty largest positive deviations, the twenty largest negative deviations, and the twenty longest durations. These extreme SET were plotted in composite plots for review.

Such composite SET plots for the cases of DUT7 CH1 and DUT8 CH1 at a LET of 28.3MeV•cm^2/mg and power supplies set to ±15V are shown in Figure 5. The SETs were bounded by maximum deviations of -0.70V and +0.57V with durations less than 2.5µs. The plot for DUT8 (right) shows a double event with the second event at about 3µs. The plots shown are representative of all the other DUT channels.

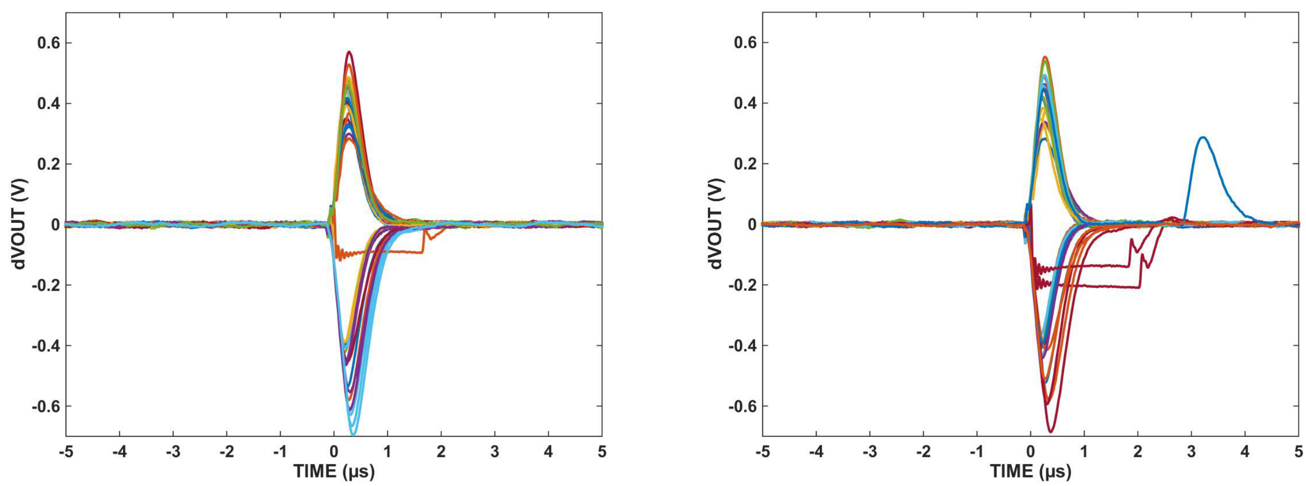

Figure 5. Composite extreme SET (20 most positive, 20 most negative, 20 longest duration outside ±80mV) plots for CH1 at LET = 28.3MeV•cm^2/mg and ±15V for DUT7 (left) and DUT8 (right)

Figure 6 shows the composite extreme SET plots for the same two parts depicted in Figure 5, but this time for power supplies were at ±5V. Although the SET durations outside of ±80mV were less than 4.5µs, there is a class of events for DUT7 that ramp slowly to the trigger level of -80mV. These events have a total duration approaching 10µs. Again, the plots are representative of the other device channels.

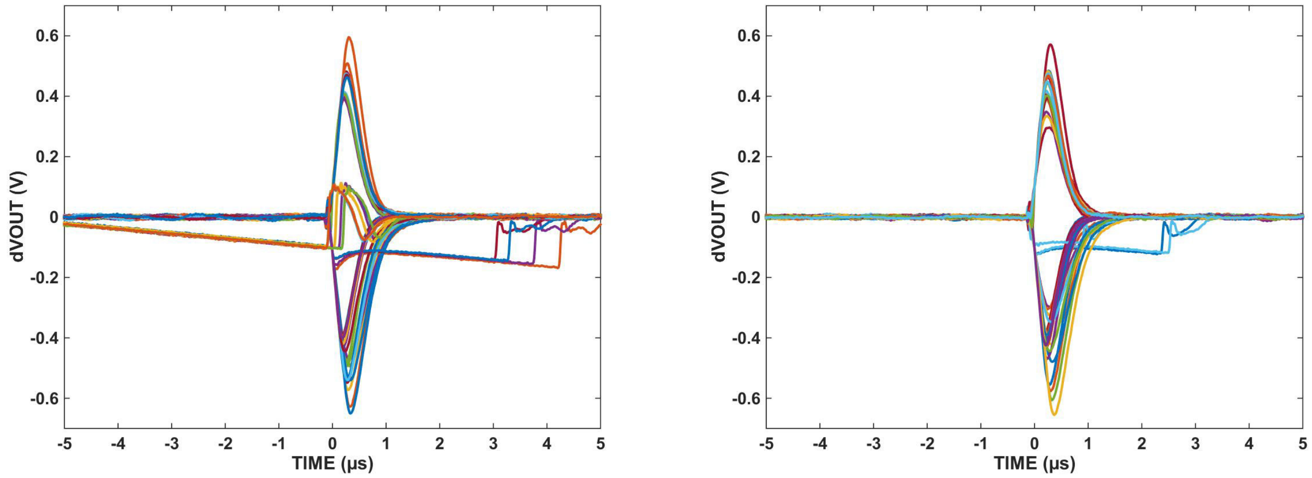

Figure 6. Composite extreme SET (20 most positive, 20 most negative, 20 longest duration outside ±80mV) plots for CH1 at LET = 28.3MeV•cm²/mg and ±5V for DUT7 (left) and DUT8 (right)

The SET size diminished along with the cross-section with decreasing LET. Examples of the SET captured for Ne irradiation for LET = 2.5MeV•cm²/mg are shown in Figure 7. These are representative of all capture collections at these conditions. All the SET captured were within ±0.25V deviation and had durations of less than 1.5µs.

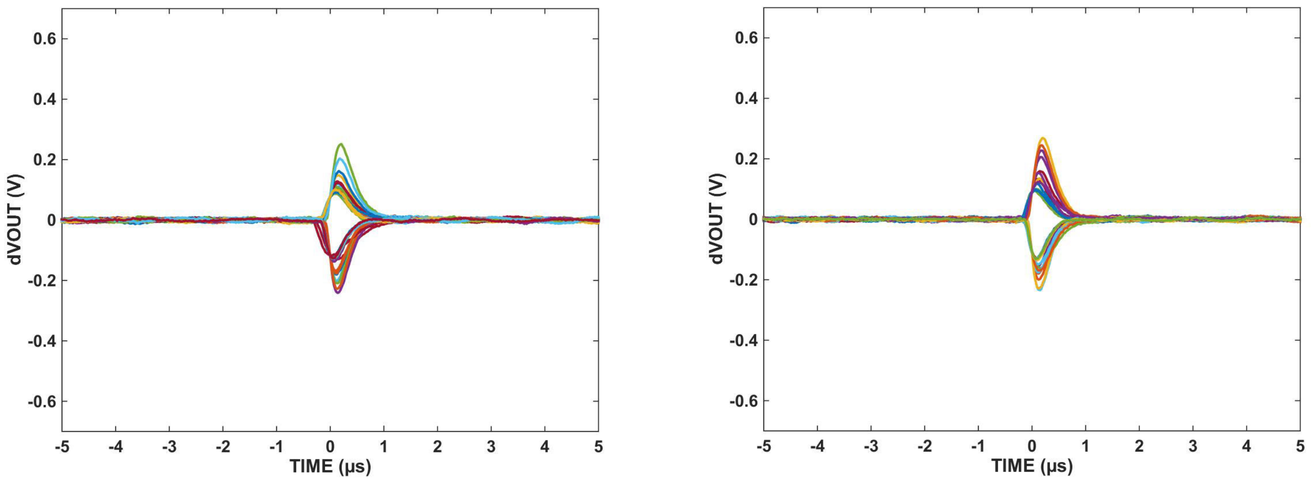

Figure 7. Composite extreme SET (20 most positive, 20 most negative, 20 longest duration outside ±80mV) plots for CH1 at LET = 2.5MeV•cm²/mg and DUT7 at ±5V (left) and DUT8 at ±15V (right)

5. Summary

The HS-OP470ARH was demonstrated to be free of destructive SEE for operation up to power supplies of ±18.2V and irradiation with normal incidence gold for a LET of 86MeV•cm²/mg. Four parts were irradiated to $2x10^6$ion/cm² while heated to a case temperature of 125°C without an indication of damage (more than 1% change in supply currents). The same parts were previously irradiated with gold to $2x10^6$ion/cm² at power supply voltages of ±16.5V and ±17.5V without any 1% change in supply currents.

The HS-OP470ARH proved to have SET over ±80mV for irradiation with neon for a LET of 2.5MeV•cm²/mg. At this irradiation, the cross-section of the 80mV events had a registered maximum of $1.21x10^{-4}$cm² when the part was operated with ±15V. At ±5V the maximum cross-section registered was $7.10x10^{-5}$cm². These maximums were found for different DUTs and different channels, DUT7 CH3 and DUT8 CH4 respectively, out of the four DUTs tested. All the SET captured for neon irradiation had durations of less than 1.5µs.

For irradiation with krypton for LET = 28.3MeV•cm^2/mg, the maximum cross sections for power supplies of ±5V and ±15V were 9.62x10^{-4}cm^2 and 1.04x10^{-3}cm^2, respectively. These extremes were found for DUT7 CH3 and DUT8 CH2, respectively. In this case, only the two DUTs were tested for this LET. Most of the SET captured had durations of less than 4.5µs but some events were recorded that had durations of up to 10µs.

6. Revision History

Rev.	Date	Description
1.00	Dec.17.19	Initial release

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