Radiation Report

TLV4H390-SEP Single-Event Effects (SEE) Radiation Report

ABSTRACT

The purpose of this study was to characterize the effects of heavy-ion irradiation on the single-event latch-up (SEL) performance of the TLV4H390-SEP high precision quad comparator. Heavy-ions with an LET_{EFF} of 50.5MeV-cm^2/mg were used to irradiate the device with a fluence of 1 × 10^7 ions/cm^2. The results demonstrate that the TLV4H390-SEP is SEL-immune up to LET_{EFF} = 43MeV-cm^2/mg at 125°C.

Characterization of single-event transients (SET) was also performed, up to a surface LET_{EFF} = 50.5MeV-cm^2 / mg at 125°C.

Table of Contents

Trademarks

All trademarks are the property of their respective owners.

1 Overview

The TLV4H390-SEP is quad channel comparator which offers low input offset voltage, fault-tolerant inputs with an excellent speed to-power combination with a propagation delay of 100ns. The TLV4H390-SEP comparator has a push-pull output stage capable of both sinking and sourcing current. See the product page for more information.

Table 1-1. Overview Information

Description	Device Information
TI Part Number	TLV4H390-SEP
MLS Number	TLV4H390MDYYTSEP
Device Function	Radiation-Tolerant High-Precision Quad Comparator in Space Enhanced Plastic
Technology	LBC9 BiCMOS
Exposure Facility	Facility for Rare Isotope Beams, Michigan State University
Heavy Ion Fluence per Run	1×10^7 ions/cm^2
Irradiation Temperature	125°C (for SEL testing)

2 SEE Mechanisms

The primary single-event effect (SEE) events of interest in the TLV4H390-SEP are single-event latch-up (SEL). From a risk and impact point-of-view, the occurrence of an SEL is potentially the most destructive SEE event and the biggest concern for space applications.

The LBC9 BiCMOS process was used for the TLV4H390-SEP. CMOS circuitry introduces a potential for SEL susceptibility. SEL can occur if excess current injection caused by the passage of an energetic ion is high enough to trigger the formation of a parasitic cross-coupled PNP and NPN bipolar structure (formed between the p-sub and n-well and n+ and p+ contacts). The parasitic bipolar structure initiated by a single-event creates a high-conductance path (inducing a steady-state current that is typically orders-of-magnitude higher than the normal operating current) between power and ground that persists (is “latched”) until power is removed or until the device is destroyed by the high-current state.

The process modifications applied for SEL-mitigation were sufficient as the TLV4H390-SEP exhibited no SEL with heavy-ions up to an LET_{EFF} of 50.5MeV-cm^2/ mg at a fluence of 10^7 ions / cm^2 and a chip temperature of 125°C.

This study was performed to evaluate the SEL effects with a bias voltage of 5.5V on V+ Supply Voltage. Heavy ions with LET_{EFF} = 50.5MeV-cm^2/ mg were used to irradiate the devices. Flux of 10^5 ions / s-cm^2 and fluence of 10^7 ions / cm^2 were used during the exposure at 125°C temperature.

3 Test Device and Test Board Information

The TLV4H390-SEP is packaged in a 14-pin, plastic SOT-23 with pinout shown in Figure 3-1.

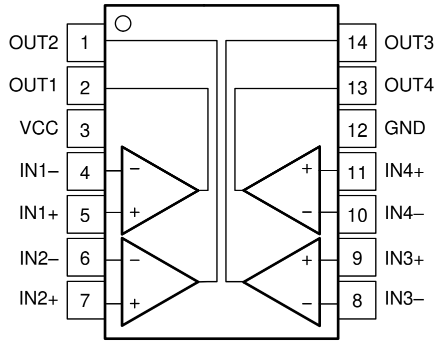

Figure 3-1. TLV4H390-SEP Pinout Diagram

Qualification Devices and Test Board

The TLV4H390-SEP was biased in either an output high or output low condition in single supply, where V+ was set to 5.5V and V- was set to GND (0V). The outputs are left floating.

To achieve an output high state, IN+ was biased with +1V and IN- was biased with +0.5V. For an output low condition, IN+ was biased with +0.5V and IN- was biased with 1V.

Heavy ions with LET_{EFF} =50.5MeV-cm^2/mg were used to irradiate the devices. A nominal flux of 10^5 ions/s-cm^2 and fluence of 10^7 ions/cm^2 were used during the exposure at 125°C.

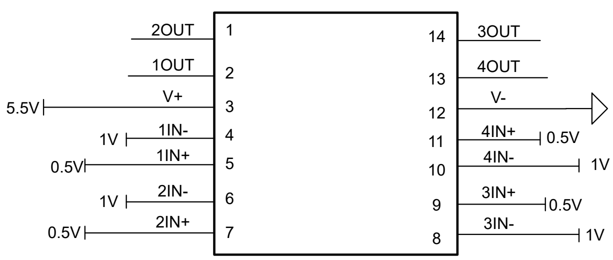

Figure 3-2. TLV4H390-SEP Bias Diagram: Output Low

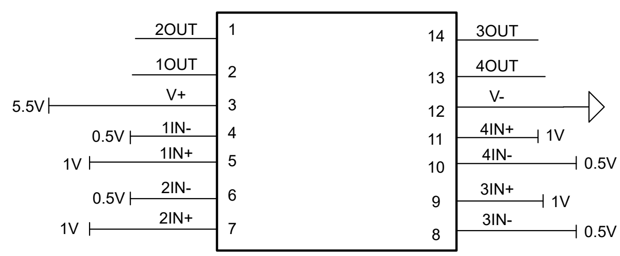

Figure 3-3. TLV4H390-SEP Bias Diagram: Output High

Figure 3-4. TLV4H390-SEP Bias Board for SEL Testing

4 Irradiation Facility and Setup

The heavy ion species used for the SEE studies on this product were provided and delivered by the Michigan State University (MSU) Facility for Rare Isotope Beams using a linear particle accelerator ion source. Ion beams were delivered with high uniformity over a 17mm × 18mm area for the in-air station.

A current-based measurement is performed on the collimating slits, which intercept 90-95% of the total beam, and this measurement is cross-calibrated against Faraday cup readings. These measurements are real-time continuous and establish dosimetry and integrated fluence. In-vacuum and in-air scintillating viewers are used for measurement of the beam size and distribution.

An ion flux of 10^5 ions/s-cm^2 was used to provide heavy ion fluences to 10^7 ions/cm^2.

5 Results

5.1 Single Event Latchup (SEL) Results

During SEL characterization, the device was heated using forced hot air, maintaining the IC temperature at 125°C. The temperature was monitored by means of a thermal camera.

The species used for the SEL testing was a Xenon (^{129}Xe) ion with an angle-of-incidence of 0° for an LET_{EFF} = 50.5 MeV-cm^2 /mg. A flux of approximately 10^5 ions/cm^2 -s and a fluence of approximately 10^7 ions were used each run.

The V+ supply voltage is supplied externally at the recommended maximum voltage setting of 5.5V. Run duration to achieve this fluence was approximately less than 2 minutes.

Two devices were tested (one at output low and the other at output high condition) where each device had a total of two runs.

Table 5-1. TLV4H390-SEP SEL Conditions Using Xe at an Angle-of-Incidence of 0°

RUN NUMBER	DUT	OUTPUT CONDITION	DISTANCE (mm)	TEMPERATURE (°C)	ION	ANGLE (deg)	FLUX (ions × cm^2/mg)	FLUENCE (# ions)	LET_{EFF} (MeV-cm^2/mg)
63	2	Low	40	125	Xe^{129}	0	10^5	10^7	50.5
64	2	Low	40	125	Xe^{129}	0	10^5	10^7	50.5
67	3	High	40	125	Xe^{129}	0	10^5	10^7	50.5
68	3	High	40	125	Xe^{129}	0	10^5	10^7	50.5

No SEL events were observed, indicating that the TLV4H390-SEP is SEL-immune at LET_{EFF} = 43MeV-cm^2/mg and T = 125°C. Combining (or summing) the fluences of the two runs at 125°C (2×10^7), the upper-bound cross-section (using a 95% confidence level) is calculated as:

$\sigma SEL \leq 1.84 \times 10^{-7}$ cm^2 for LET_{EFF} = 43MeV-cm^2/mg and T = 125°C.

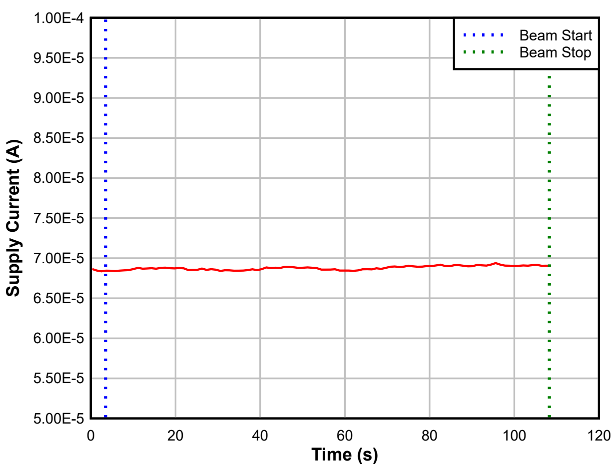

Figure 5-1. Run #68: DUT3 Supply Current vs. Time: Output High

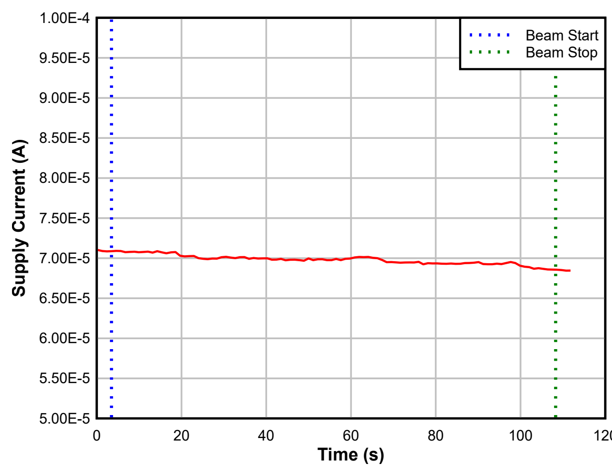

Figure 5-2. Run #67: DUT3 Supply Current vs. Time: Output High

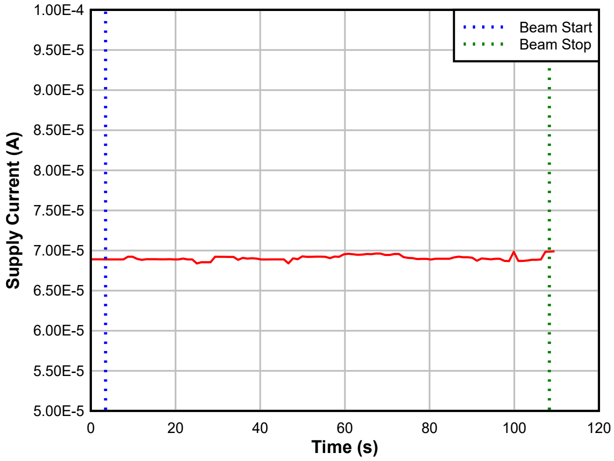

Figure 5-3. Run #64: DUT2 Supply Current vs. Time: Output Low

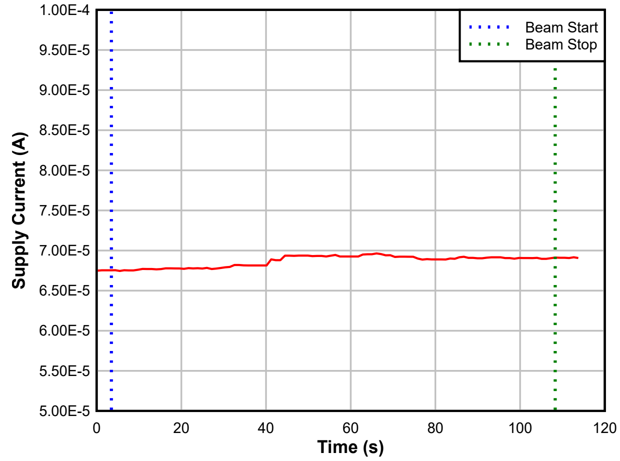

Figure 5-4. Run #63: DUT2 Supply Current vs. Time: Output Low

5.2 Single Event Transient (SET) Results

The TLV4H390-SEP was characterized from 50.5 to 1MeV-cm^2/ mg at 1.65V and 3.3V supply voltages in both output high and output low configuration. The device was tested at room temperature for all SETs runs. A nominal flux of 10^5 ions / s-cm^2 was used, with each run concluding once a fluence of 10^7 ions/cm^2 was reached. The device was tested at approximately 25°C as exposed to six LET_{EFF} readpoints of 50.5 MeV-cm^2/ mg, 35.6 MeV-cm^2/ mg, 23.1 MeV-cm^2 / mg, 9.8 MeV-cm^2/mg, 5.3 MeV-cm^2/mg, and 1.0 MeV-cm^2/mg. The output was monitored with an oscilloscope set to a window trigger mode that captured any events where the output shifted by ±250mV or more. The event counts are the sum of all the channels. The conditions and results for each run are summarized in the tables below. See SET Results Appendix for histograms of the transient magnitudes and transient waveforms.

Table 5-2. SET Run Summary for TLV4H390-SEP in Output High Condition

RUN NUMBER	DUT NUMBER	OUTPUT CONDITION	TEMPERATURE (°C)	ION	ANGLE (deg)	AVERAGE FLUX (ions × cm²/mg)	FLUENCE (Number of ions)	LET_{EFF} (MeV·cm²/mg)	V_{CC} (V)	NUMBER OF EVENTS
55	1	High	25	^{129}Xe	0	1.00E+0.5	1.00E+07	50.5	1.65	258
56	1	High	25	^{129}Xe	0	1.00E+0.5	1.00E+07	50.5	3.3	366
127	1	High	25	^{129}Xe	0	1.00E+0.5	1.00E+07	35.6	1.65	209
128	1	High	25	^{129}Xe	0	1.00E+0.5	1.00E+07	35.6	3.3	248
136	1	High	25	^{129}Xe	0	1.00E+0.5	1.00E+07	23.1	1.65	156
137	1	High	25	^{129}Xe	0	1.00E+0.5	1.00E+07	23.1	3.3	206
231	1	High	25	^{40}Ar	0	1.00E+0.5	1.00E+07	9.8	1.65	122
234	1	High	25	^{40}Ar	0	1.00E+0.5	1.00E+07	9.8	3.3	124
244	1	High	25	^{40}Ar	0	1.00E+0.5	1.00E+07	5.3	1.65	159
245	1	High	25	^{40}Ar	0	1.00E+0.5	1.00E+07	5.3	3.3	152
276	1	High	25	^{16}O	0	1.00E+0.5	1.00E+07	1	1.65	33
277	1	High	25	^{16}O	0	1.00E+0.5	1.00E+07	1	3.3	32

Table 5-3. SET Run Summary for TLV4H390-SEP in Output Low Condition

RUN NUMBER	DUT NUMBER	OUTPUT CONDITION	TEMPERATURE (°C)	ION	ANGLE (deg)	AVERAGE FLUX (ions × cm²/mg)	F (NUMBER OF IONS)	LET_{EFF} (MeV × cm²/mg)	V_{CC} (V)	# of Events
61	1	Low	25	^{129}Xe	0	1.00E+0.5	1.00E+07	50.5	1.65	243
62	1	Low	25	^{129}Xe	0	1.00E+0.5	1.00E+07	50.5	3.3	308k[1]
131	1	Low	25	^{129}Xe	0	1.00E+0.5	1.00E+07	35.6	1.65	180
132	1	Low	25	^{129}Xe	0	1.00E+0.5	1.00E+07	35.6	3.3	236
139	1	Low	25	^{129}Xe	0	1.00E+0.5	1.00E+07	23.1	1.65	161
140	1	Low	25	^{129}Xe	0	1.00E+0.5	1.00E+07	23.1	3.3	200
237	1	Low	25	^{40}Ar	0	1.00E+0.5	1.00E+07	9.8	1.65	142
238	1	Low	25	^{40}Ar	0	1.00E+0.5	1.00E+07	9.8	3.3	162
240	1	Low	25	^{40}Ar	0	1.00E+0.5	1.00E+07	5.3	1.65	102
241	1	Low	25	^{40}Ar	0	1.00E+0.5	1.00E+07	5.3	3.3	155
279	1	Low	25	^{16}O	0	1.00E+0.5	1.00E+07	1	1.65	12
280	1	Low	25	^{16}O	0	1.00E+0.5	1.00E+07	1	3.3	10

Figure 5-5 through Figure 5-8 show two examples of a typical transient event at 3.3V supply and LET_{EFF} = 50.5MeV-cm^2 / mg. The corresponding supply current was also recorded.

[1] Believed to be a triggering setup error. Out of proportion to other data.

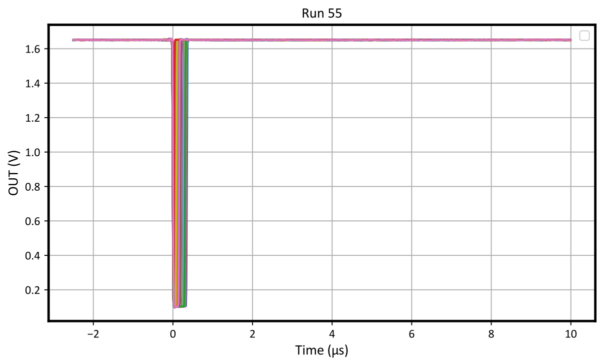

Figure 5-5. Run 55, Channel 1, All Events, Output High

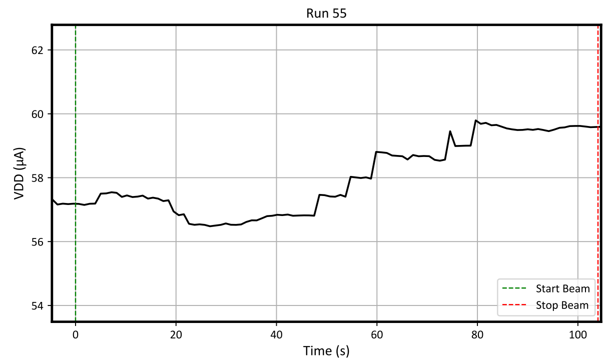

Figure 5-6. Run 55, All Events, Supply Current, Output High

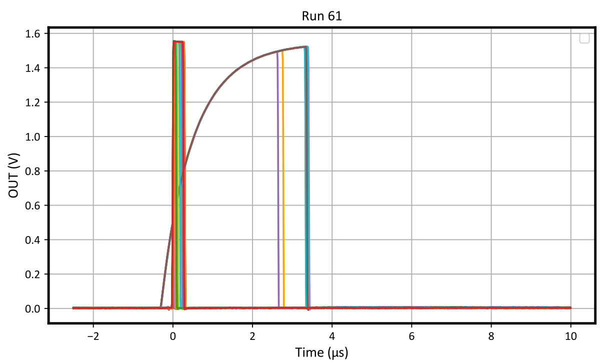

Figure 5-7. Run 61, Channel 1, All Events, Output Low

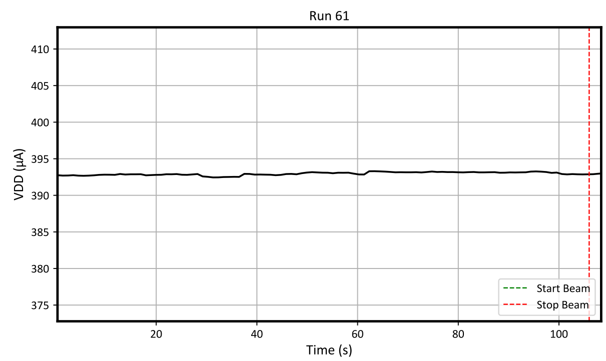

Figure 5-8. Run 61, All Events, Total Supply Current, Output Low

6 Summary

Radiation effects of the radiation tolerant high speed comparator in space enhanced plastic TLV4H390-SEP was studied. This device passed total dose rate of up to 30krad(Si) and is SEL immune up to LET_{EFF} = 43MeV-cm^2/mg and T = 125°C. SET characterization of the device was also conducted.

7 References

1. M. Shoga and D. Binder, *Theory of Single Event Latchup in Complementary Metal-Oxide Semiconductor Integrated Circuits*, *IEEE Trans. Nucl. Sci., Vol. 33(6)*, Dec. 1986, pp. 1714-1717.
2. G. Bruguier and J. M. Palau, *Single particle-induced latchup*, *IEEE Trans. Nucl. Sci., Vol. 43(2)*, Mar. 1996, pp. 522-532.
3. Michigan State University, *Michigan State University (MSU) Facility for Rare Isotope Beams (FRIB)*, webpage.
4. Ziegler, James F. *The Stopping and Range of Ions in Mattet*, webpage.
5. D. Kececioglu, *Reliability and Life Testing Handbook,* Vol. 1, PTR Prentice Hall, New Jersey,1993, pp. 186-193.
6. Vanderbilt University, *ISDE CRÈME-MC*, webpage.
7. A. J. Tylka, J. H. Adams, P. R. Boberg, et al.,*CREME96: A Revision of the Cosmic Ray Effects on Micro-Electronics Code*, *IEEE Trans. on Nucl. Sci., Vol. 44(6)*, Dec. 1997, pp. 2150-2160.
8. A. J. Tylka, W. F. Dietrich, and P. R. Boberg, *Probability distributions of high-energy solar-heavy-ion fluxes from IMP-8: 1973-1996, IEEE Trans. on Nucl. Sci.,Vol. 44(6)*, Dec. 1997, pp. 2140-2149.

A SET Results Appendix

The SET histogram graphs are shown in the following section.