Application Note

TLV1704-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 TLV1704-SEP 2.2V to 24V, microPower comparator. Heavy-ions with an LET_{EFF} of 43MeV-cm^2/ mg were used to irradiate the devices with a fluence of 1×10^7 ions/cm^2. The results demonstrate that the TLV1704-SEP is SEL-free 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} = 50MeV-cm2 / mg at 125°C.

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Trademarks

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1 Overview

The TLV1704-SEP (Quad) device offers a wide supply range, rail-to-rail inputs, low quiescent current, and low propagation delay. All these features come in industry-standard, extremely-small packages, making these devices the best general-purpose comparators available. The open collector output offers the advantage of allowing the output to be pulled to any voltage rail up to +24 V above the negative power supply regardless of the TLV1704-SEP supply voltage. The device is a microPower comparator. Low input offset voltage, low input bias currents, low supply current, and open-collector configuration makes the TLV1704-SEP device flexible enough to handle almost any application, from simple voltage detection to driving a single relay.

www.ti.com/product/TLV1704-SEP/technicaldocuments

Table 1-1. Overview Information

DESCRIPTION	DEVICE INFORMATION
TI Part Number	TLV1704-SEP
MLS Number	TLV1704AMPWTPSEP
Device Function	Radiation Hardened microPower Quad Comparator in Space Enhanced Plastic
Technology	BICOM3XHV
Exposure Facility	Facility for Rare Isotope Beams, Michigan State University
Heavy Ion Fluence per Run	$1{\times}10^7$ ions/cm^2
Irradiation Temperature	125°C (for SEL testing)

2 SEE Mechanisms

The primary single-event effect (SEE) events of interest in the TLV1704-SEP are single-event latch-up (SEL). From a risk/impact point-of-view, the occurrence of an SEL is potentially the most destructive SEE event and the biggest concern for space applications. The BICOM3XHV was used for the TLV1704-SEP. CMOS circuitry introduces a potential for SEL and SEB 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 TLV1704-SEP exhibited no SEL with heavy-ions up to an LET_{EFF} of 43 MeV-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 24V on V_S Supply Voltage. Heavy ions with LET_{EFF} = 43 MeV-cm^2/mg were used to irradiate the devices. Flux of 10^5 ions/s-cm^2 and fluence of 10^7 ions were used during the exposure at 125°C temperature.

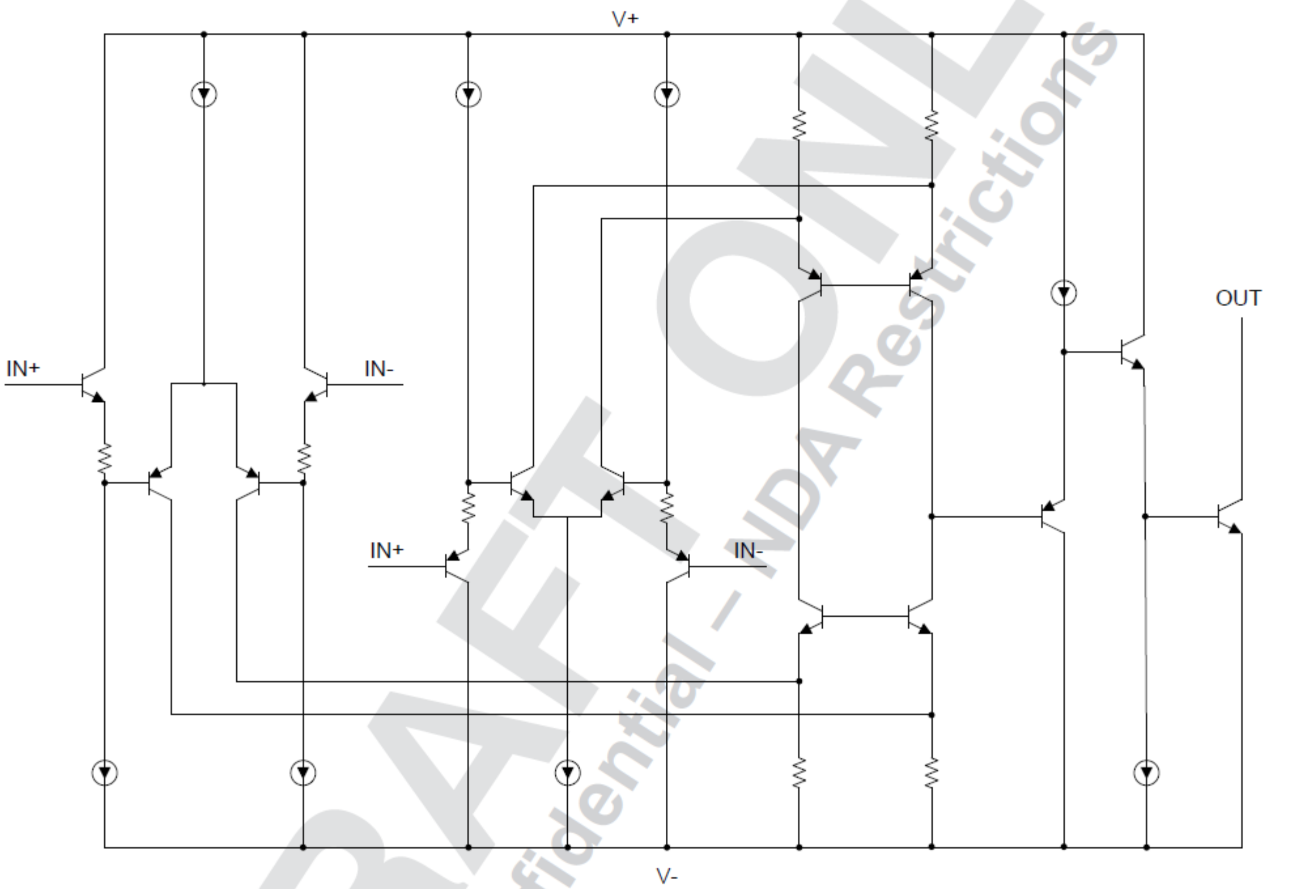
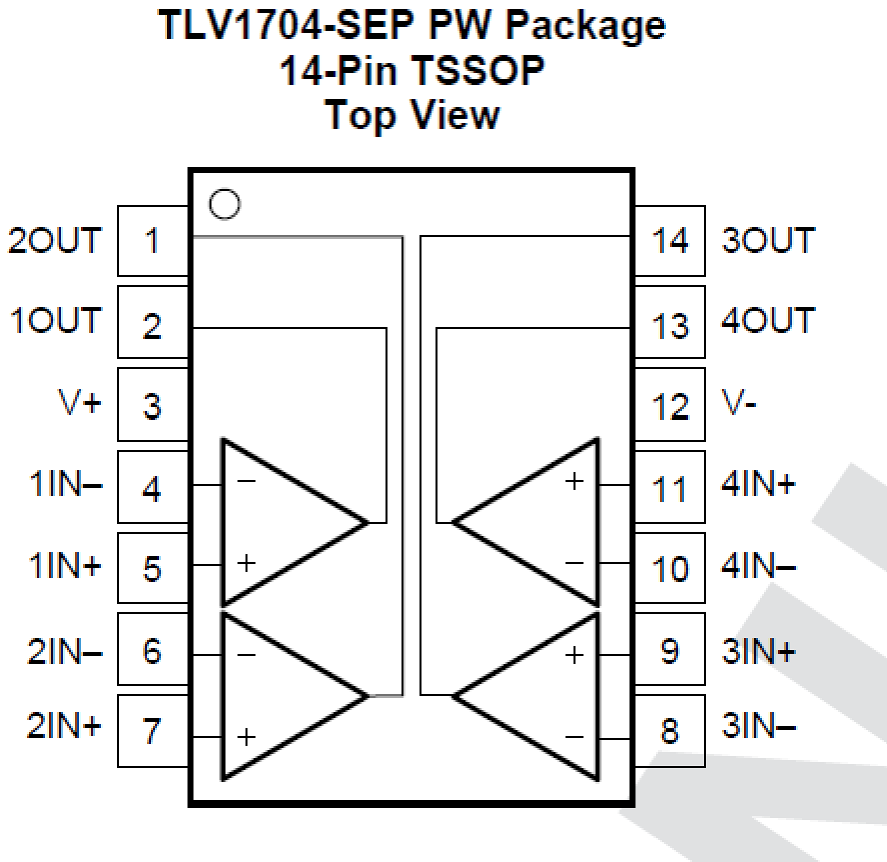


Figure 2-1. Functional Block Diagram of the TLV1704-SEP

3 Test Device and Test Board Information

The TLV1704-SEP is packaged in a 14-pin, TSSOP shown with pinout in Figure 3-1. The TLV1704-SEP bias board is used for the SEE characterization is shown in Figure 3-2 and bias diagram in Figure 3-3.



TLV1704-SEP pinout diagram. The package was decap'ed to reveal the die face for all heavy ion testing.

Figure 3-1. TLV1704-SEP Pinout Diagram

Qualification Devices and Test

The TLV1704-SEP was biased in either an output high or output low condition in single supply, where V_+ was set to 24V and V_- was set to GND (0V). All non-inverting inputs of each channel were tied together; likewise, all inverting inputs of each channel were tied together. To achieve an output high state, IN+ was biased with 3V and IN- was biased with 2V. For an output low condition, IN+ was biased with 2V and IN- was biased with 3V. A nominal flux of 10^5 ions / s-cm^2 and fluence of 10^7 ions / cm^2 were used for each run during the exposure at 125°C.

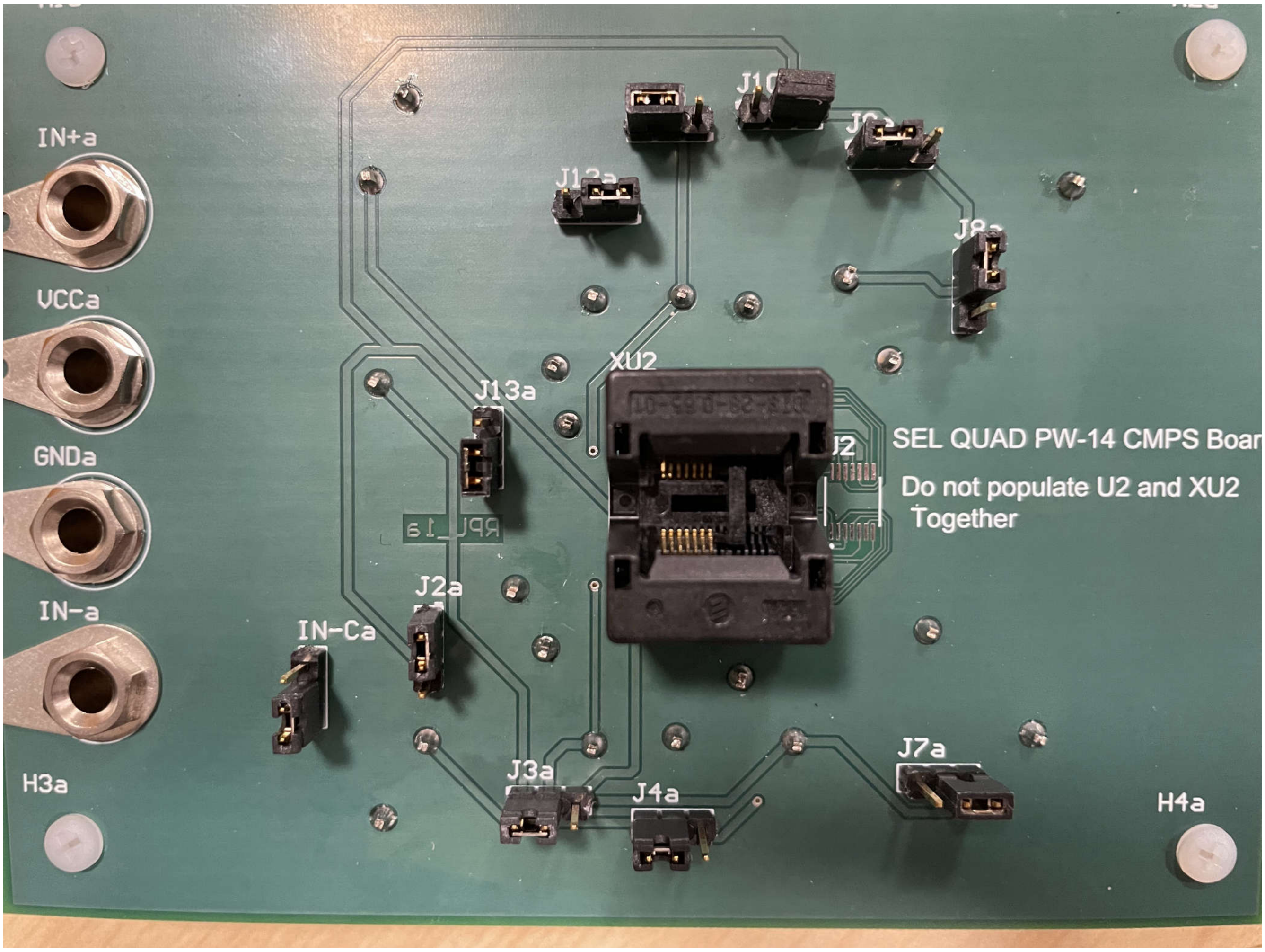


Figure 3-2. TLV1704-SEP Bias Board

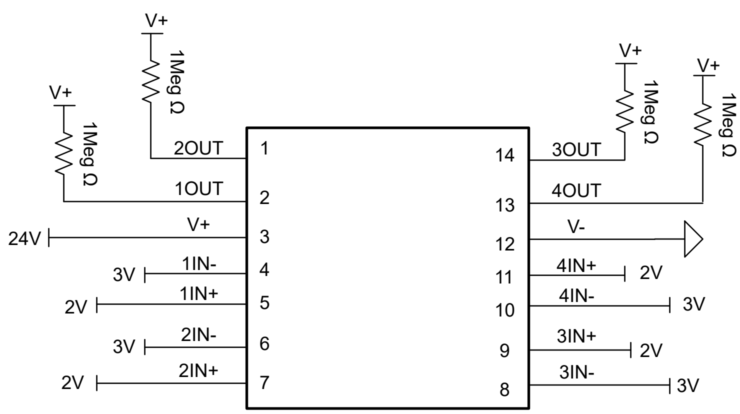


Figure 3-3. TLV1704-SEP Bias Diagram

4 Irradiation Facility and Setup

The heavy ion species used for the SEE studies on this product were provided and delivered by the MSU Faciltiy 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_s supply voltage is supplied externally on board at recommended maximum voltage setting of 24V. Run duration to achieve this fluence was approximately less than 2 minutes. Three devices were tested at an output low condition where each device had a total of two runs.

Table 5-1. TLV1704-SEP SEL Conditions Using ^{129}Xe at an Angle-of-Incidence of 0°

RUN #	DUT	DISTANCE (mm)	TEMPERATURE (°C)	ION	ANGLE (°)	FLUX (ions·cm^2/mg)	FLUENCE (# ions)	LET_{EFF} (MeV.cm^2/mg)
24	3	70	125	Xe	0	1.00E+05	1.00E+07	50.5
25	3	70	125	Xe	0	1.00E+05	1.00E+07	50.5
76	7	70	125	Xe	0	0.997E+05	1.00E+07	50.5
77	7	70	125	Xe	0	1.01E+05	1.00E+07	50.5
82	8	70	125	Xe	0	1.01E+05	1.00E+07	50.5
83	8	70	125	Xe	0	1.01E+05	1.00E+07	50.5

No SEL events were observed, indicating that the TLV1704-SEP is SEL-immune at LET_{EFF} = 43 MeV-cm^2/mg and T = 125°C. Using the MFTF method described in Section 8 and combining (or summing) the fluences of the two runs @ 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} = 43 MeV-cm^2/mg and T = 125°C.

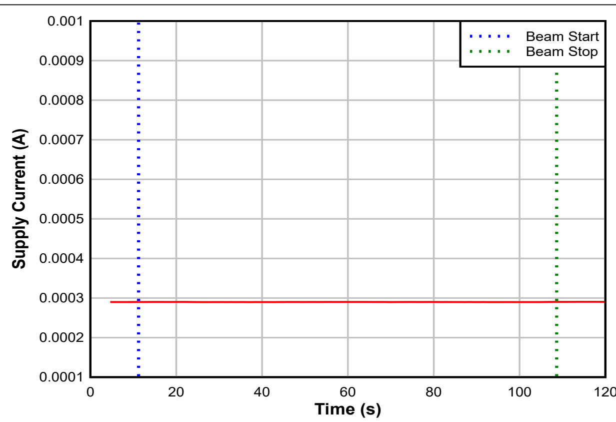


Figure 5-1. Run #24: DUT3 Supply Current vs. Time

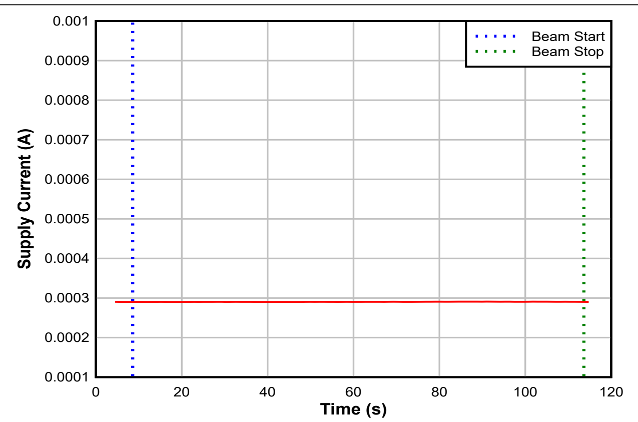


Figure 5-2. Run #25: DUT3 Supply Current vs. Time

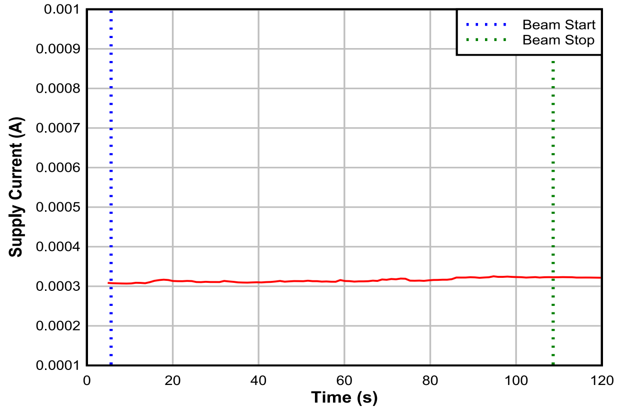


Figure 5-3. Run #76: DUT7 Supply Current vs. Time

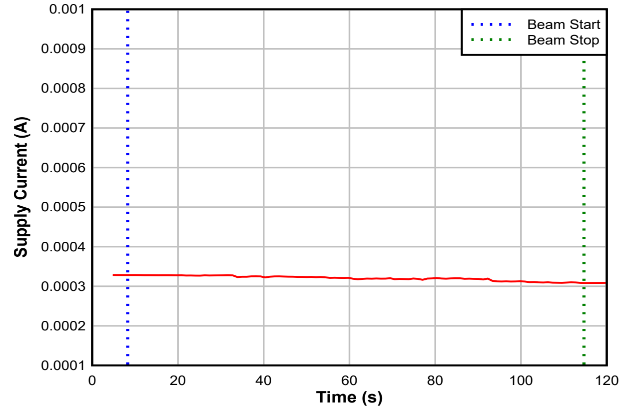


Figure 5-4. Run #77: DUT7 Supply Current vs. Time

5.2 Single Event Transient (SET) Results

The TLV1704-SEP was characterized from 50.5 to 1.0 MeV-cm^2 / mg at 3.3V, 12V, and 24V 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 while 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 the oscilloscope set to a window trigger mode that captured any events where the output shifted by ±500mV or more. The conditions and results for each run are summarized in the tables below. Figure 5-7 to Figure 5-10 show two examples of typical transient events at 24V supply and LET_{EFF} = 50.5 MeV-cm2 / mg. The corresponding supply current was also recorded. See SET Results Appendix for histograms of the transient magnitudes and typical waveforms of the transients themselves.

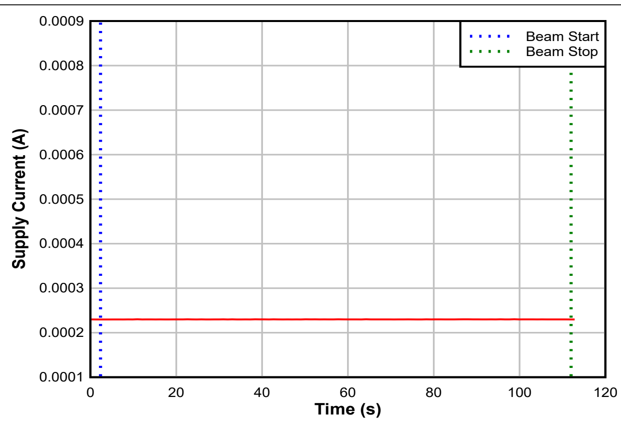


Figure 5-5. Run #97 Supply Current

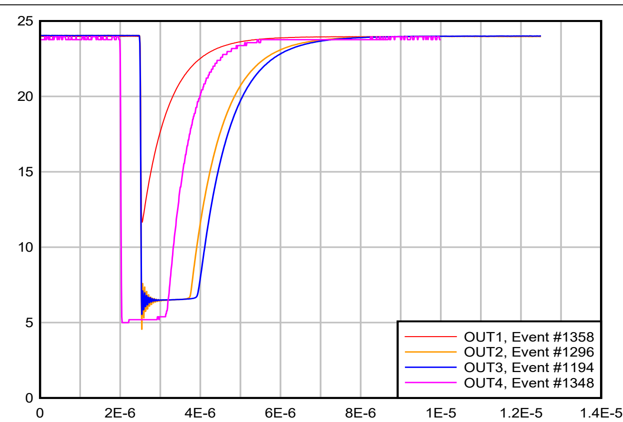


Figure 5-6. Run #97 Typical Transient Waveforms

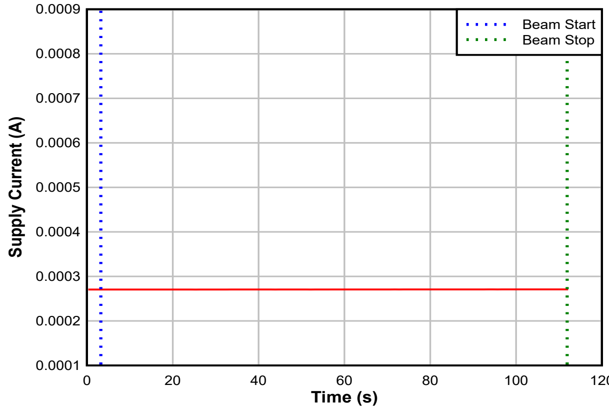


Figure 5-7. Run #99 Supply Current

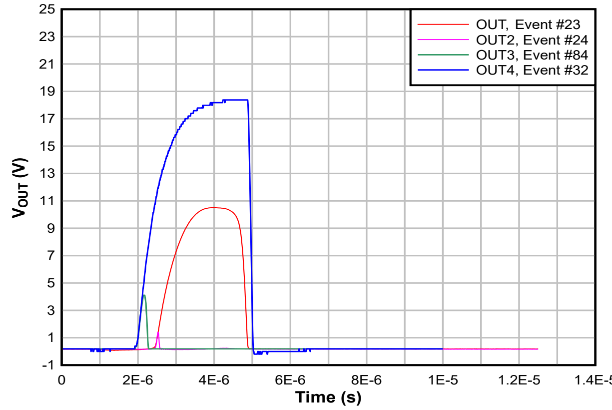


Figure 5-8. Run #99 Typical Transient Waveforms

Table 5-2. SET Run Summary for TLV1704-SEP in Output High Condition

RUN #	DUT	Output Condition	TEMPERATURE (°C)	ION	ANGLE	FLUX (ions·cm²/ mg)	FLUENCE (# ions)	LET_{EFF} (MeV.cm²/ mg)	$V_s = V_{s+} - V_{s-}$	# of Events
90	20	High	25	Xe	0	0.98 E+05	1.00 E+07	50.5	3.3	5868
91	20	High	25	Xe	0	0.98 E+05	1.00 E+07	50.5	12	7689
97	20	High	25	Xe	0	1.11 E+05	1.00 E+07	50.5	24	7255
155	20	High	25	Kr	0	1.11 E+05	1.00 E+07	35.6	3.3	4825
156	20	High	25	Kr	0	1.07 E+05	1.00 E+07	35.6	12	5857
158	20	High	25	Kr	0	1.11 E+05	1.00 E+07	35.6	24	5621
165	20	High	25	Kr	0	1.06 E+05	1.00 E+07	23.1	3.3	1236
166	20	High	25	Kr	0	1.08 E+05	1.00 E+07	23.1	12	3664
167	20	High	25	Kr	0	1.09 E+05	1.00 E+07	23.1	24	4358
248	20	High	25	Ar	0	1.03 E+05	1.00 E+07	9.8	3.3	286
249	20	High	25	Ar	0	1.03 E+05	1.00 E+07	9.8	12	533
252	20	High	25	Ar	0	1.05 E+05	1.00 E+07	9.8	24	870
259	20	High	25	Ar	0	1.07 E+05	1.00 E+07	5.3	3.3	84
260	20	High	25	Ar	0	1.06 E+05	1.00 E+07	5.3	12	118
261	20	High	25	Ar	0	1.07 E+05	1.00 E+07	5.3	24	90
262	20	High	25	O	0	1.00 E+05	1.00 E+07	1.0	3.3	0
265	20	High	25	O	0	1.00 E+05	1.00 E+07	1.0	12	0

Table 5-2. SET Run Summary for TLV1704-SEP in Output High Condition (continued)

RUN #	DUT	Output Condition	TEMPERATURE (°C)	ION	ANGLE	FLUX (ions·cm²/mg)	FLUENCE (# ions)	LET_{EFF} (MeV.cm²/mg)	$V_s = V_{s+} - V_{s-}$	# of Events
267	20	High	25	O	0	0.99 E+05	1.00 E+07	1.0	24	0

Table 5-3. SET Run Summary for TLV1704-SEP in Output Low Condition

RUN #	DUT	Output Condition	TEMPERATURE (°C)	ION	ANGLE	FLUX (ions·cm²/mg)	FLUENCE (# ions)	LET_{EFF} (MeV.cm²/mg)	$V_s = V_{CC} - V_{EE}$	# of Events
92	20	Low	25	Xe	0	0.97 E+05	1.00 E+07	50.5	3.3	566
93	20	Low	25	Xe	0	0.98 E+05	1.00 E+07	50.5	12	5831
99	20	Low	25	Xe	0	0.97 E+05	1.00 E+07	50.5	24	3561
159	20	Low	25	Kr	0	1.06 E+05	1.00 E+07	35.6	3.3	371
160	20	Low	25	Kr	0	1.06 E+05	1.00 E+07	35.6	12	4036
161	20	Low	25	Kr	0	1.06 E+05	1.00 E+07	35.6	24	5171
162	20	Low	25	Kr	0	1.08 E+05	1.00 E+07	23.1	3.3	334
163	20	Low	25	Kr	0	1.07 E+05	1.00 E+07	23.1	12	1357
164	20	Low	25	Kr	0	1.04 E+05	1.00 E+07	23.1	24	3522
253	20	Low	25	Ar	0	1.05 E+05	1.00 E+07	9.8	3.3	271
254	20	Low	25	Ar	0	1.05 E+05	1.00 E+07	9.8	12	553
255	20	Low	25	Ar	0	1.04 E+05	1.00 E+07	9.8	24	668
256	20	Low	25	Ar	0	1.06 E+05	1.00 E+07	5.3	3.3	107
257	20	Low	25	Ar	0	1.08 E+05	1.00 E+07	5.3	12	227
258	20	Low	25	Ar	0	1.08 E+05	1.00 E+07	5.3	24	270
268	20	Low	25	O	0	1.01 E+05	1.00 E+07	1.0	3.3	46
270	20	Low	25	O	0	1.01 E+05	1.00 E+07	1.0	12	28
271	20	Low	25	O	0	1.02 E+05	1.00 E+07	1.0	24	65

6 Summary

Radiation effects Radiation Hardened microPower Quad Comparator in Space Enhanced Plastic TLV1704-SEP was studied. This device passed total dose rate of up to 30 krad(Si) and is latch-up immune up to LET_{EFF} = 43 MeV-cm^2/mg and T = 125°C.

7 SET Results Appendix

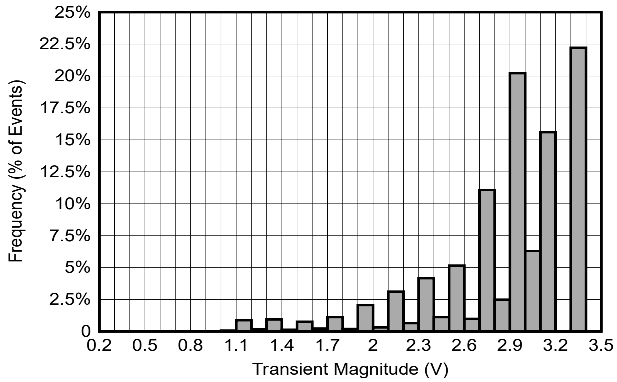


Figure 7-1. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 50.5MeV-cm^2 / mg, Output High Condition

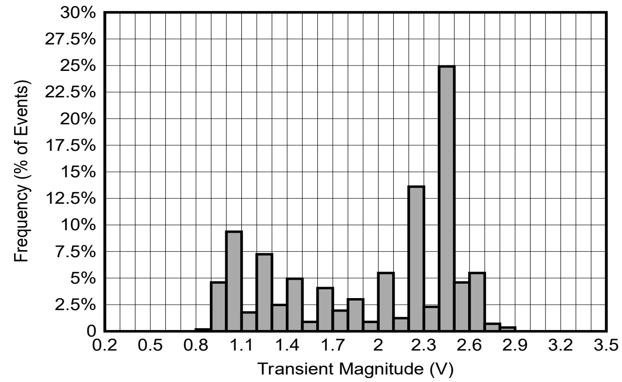


Figure 7-2. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 50.5MeV-cm^2 / mg, Output Low Condition

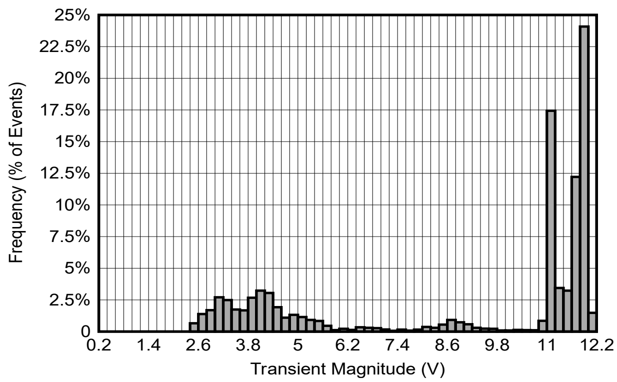


Figure 7-3. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 50.5MeV-cm^2 / mg, Output High Condition

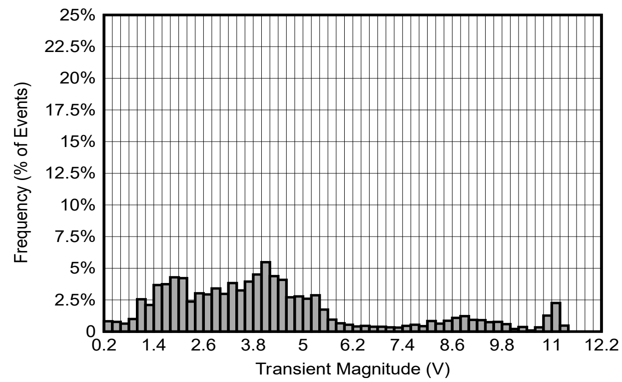


Figure 7-4. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 50.5MeV-cm^2 / mg, Output Low Condition

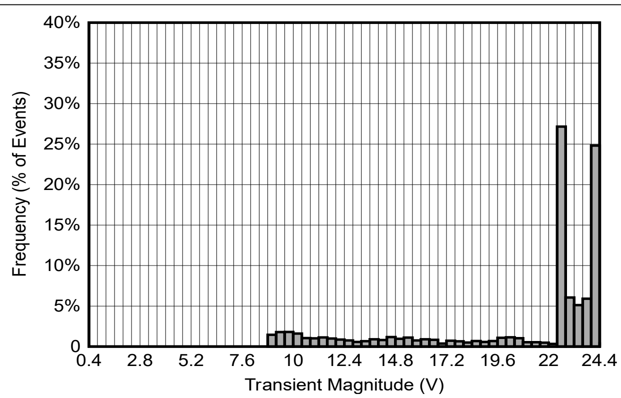


Figure 7-5. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 50.5MeV-cm^2 / mg, Output High Condition

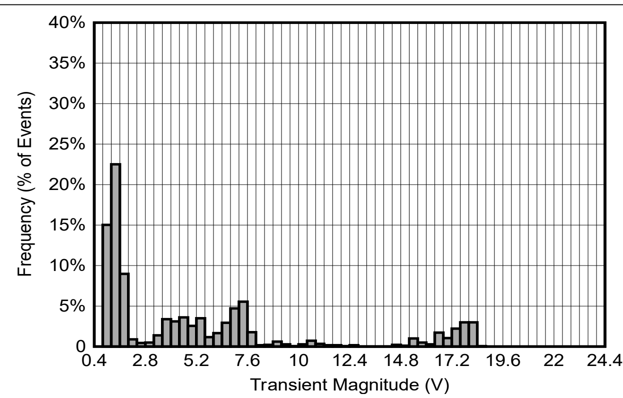


Figure 7-6. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 50.5MeV-cm^2 / mg, Output Low Condition

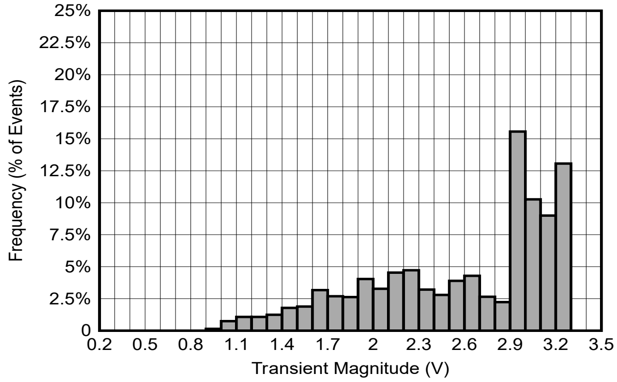


Figure 7-7. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 35.6MeV-cm^2 / mg, Output High Condition

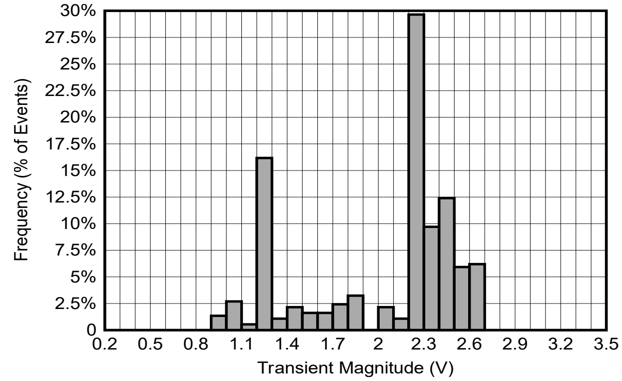


Figure 7-8. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 35.6MeV-cm^2 / mg, Output Low Condition

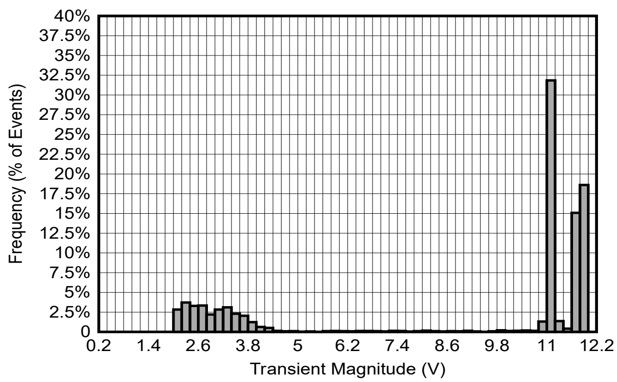


Figure 7-9. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 35.6MeV-cm^2 / mg, Output High Condition

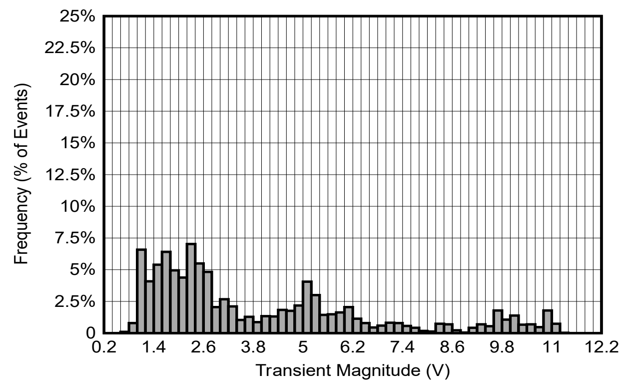


Figure 7-10. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 35.6MeV-cm^2 / mg, Output Low Condition

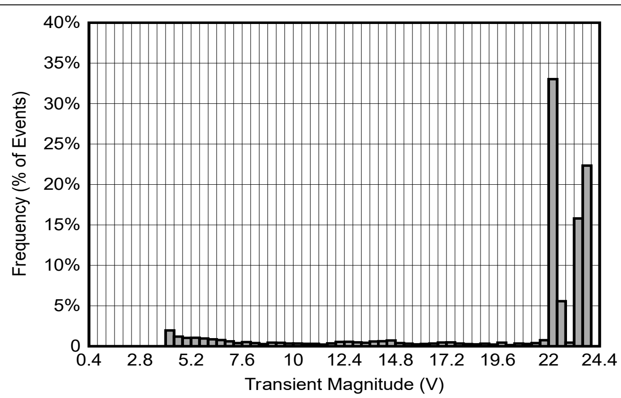


Figure 7-11. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 35.6MeV-cm^2 / mg, Output High Condition

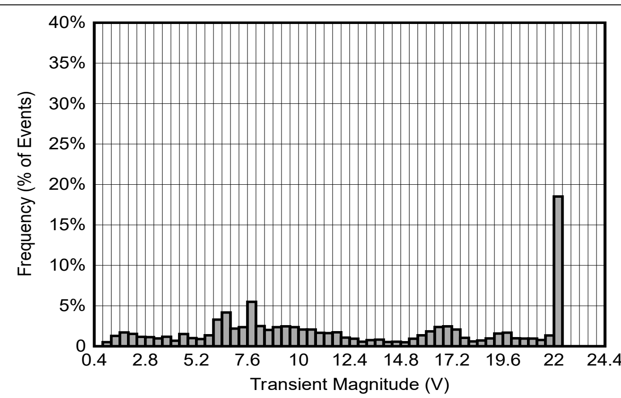


Figure 7-12. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 35.6MeV-cm^2 / mg, Output Low Condition

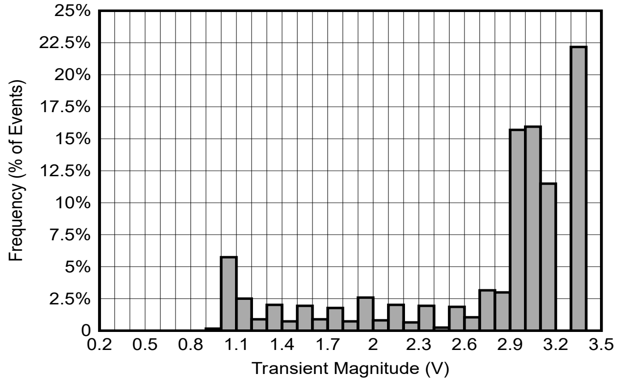


Figure 7-13. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 23.1MeV-cm^2 / mg, Output High Condition

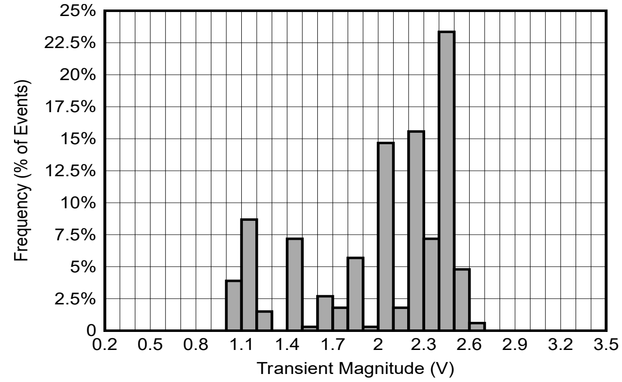


Figure 7-14. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 23.1MeV-cm^2 / mg, Output Low Condition

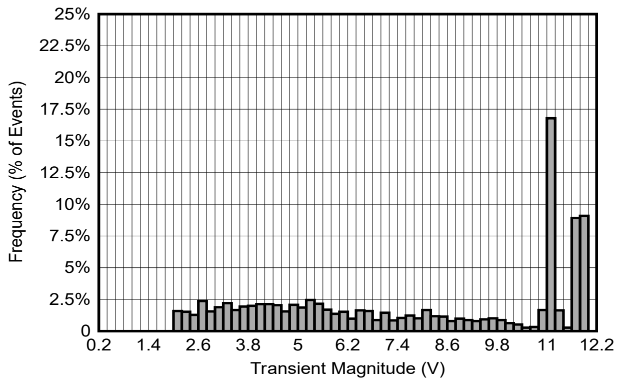


Figure 7-15. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 23.1MeV-cm^2 / mg, Output High Condition

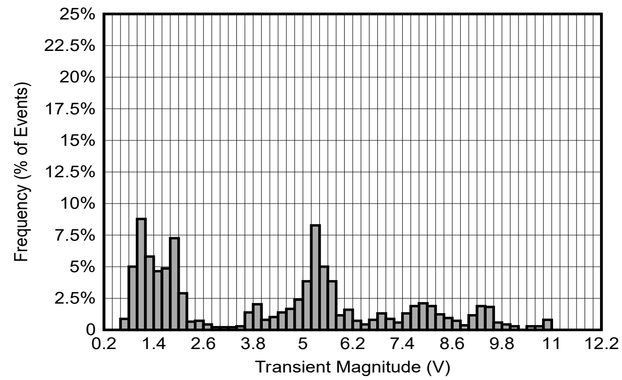


Figure 7-16. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 23.1MeV-cm^2 / mg, Output Low Condition

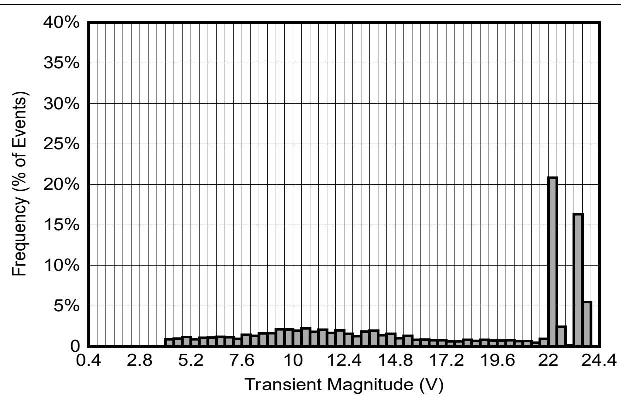


Figure 7-17. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 23.1MeV-cm^2 / mg, Output High Condition

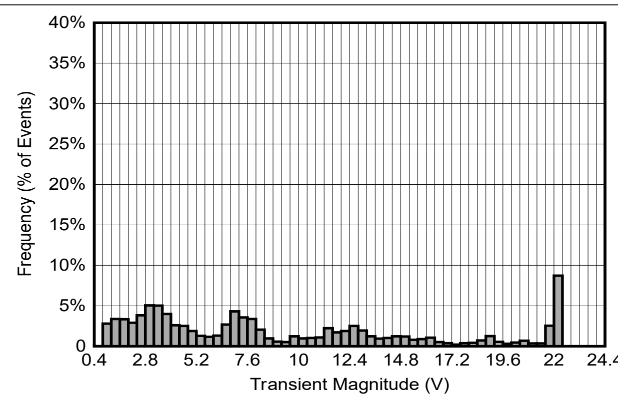


Figure 7-18. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 23.1MeV-cm^2 / mg, Output Low Condition

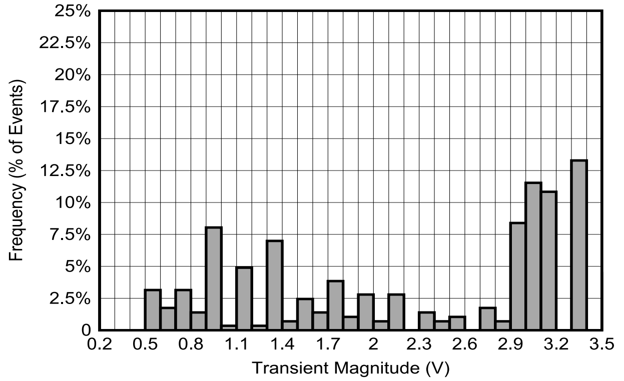


Figure 7-19. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 9.8MeV-cm^2 / mg, Output High Condition

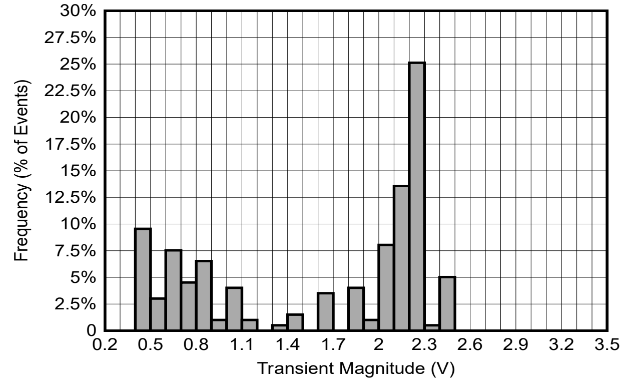


Figure 7-20. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 9.8MeV-cm^2 / mg, Output Low Condition

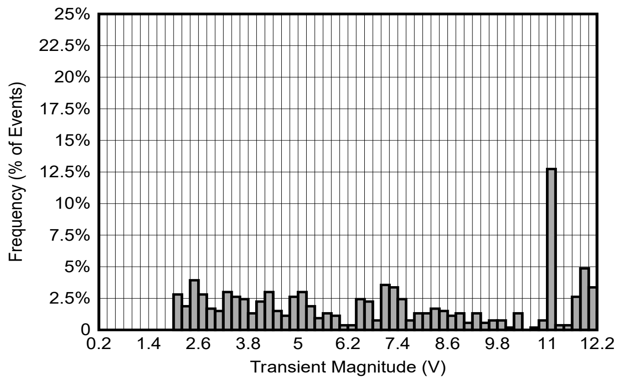


Figure 7-21. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 9.8MeV-cm^2 / mg, Output High Condition

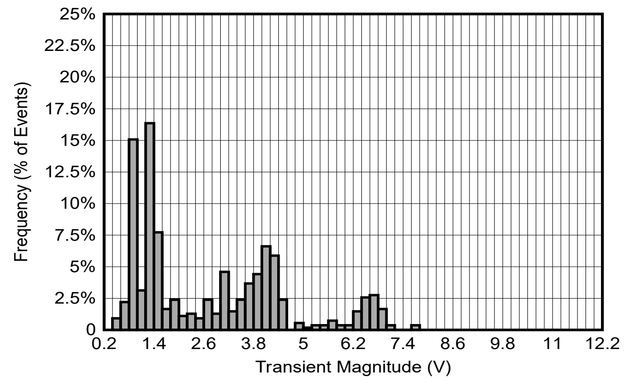


Figure 7-22. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 9.8MeV-cm^2 / mg, Output Low Condition

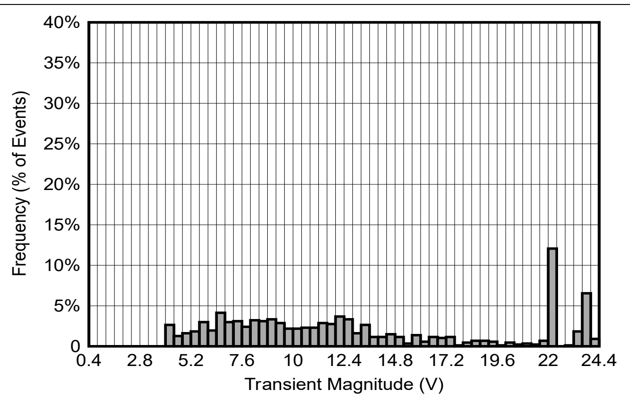


Figure 7-23. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 9.8MeV-cm^2 / mg, Output High Condition

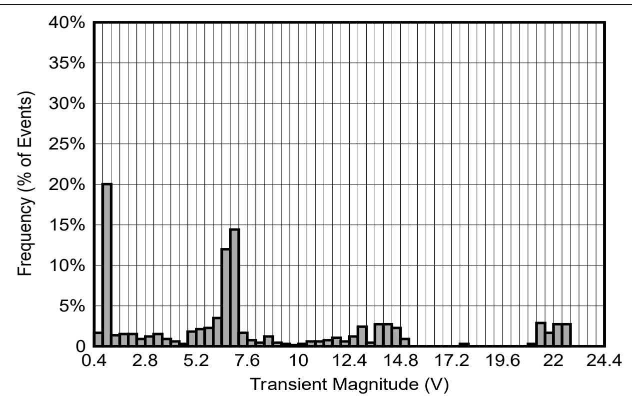


Figure 7-24. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 9.8MeV-cm^2 / mg, Output Low Condition

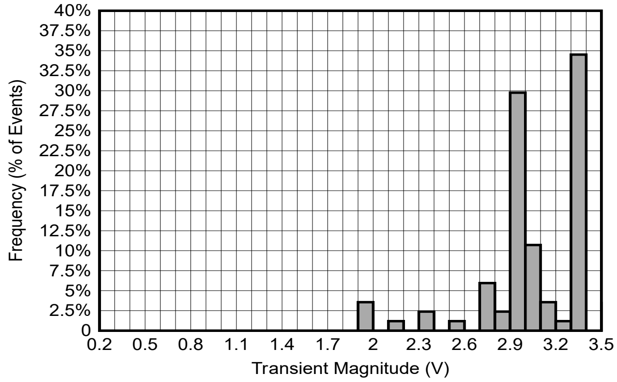


Figure 7-25. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 5.3MeV-cm^2 / mg, Output High Condition

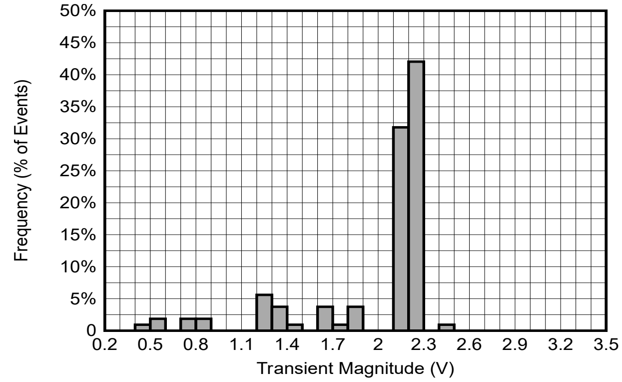


Figure 7-26. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 5.3MeV-cm^2 / mg, Output Low Condition

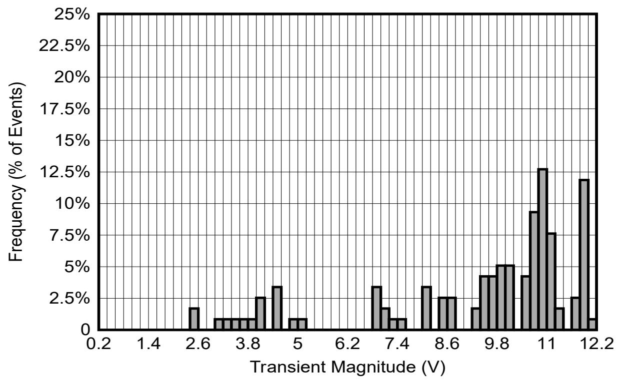


Figure 7-27. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 5.3MeV-cm^2 / mg, Output High Condition

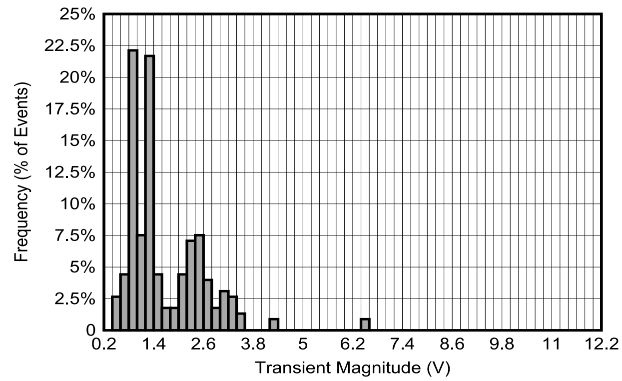


Figure 7-28. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} = 5.3MeV-cm^2 / mg, Output Low Condition

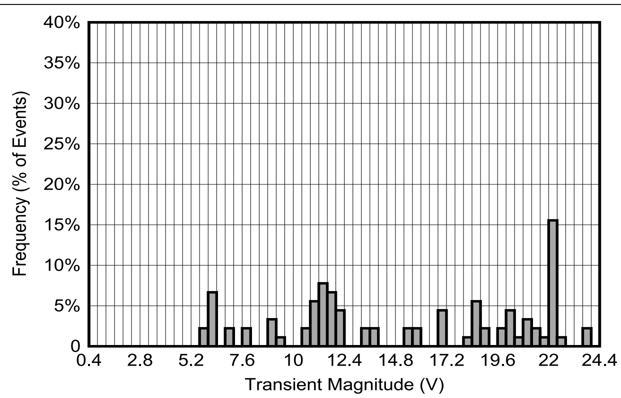


Figure 7-29. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 5.3MeV-cm^2 / mg, Output High Condition

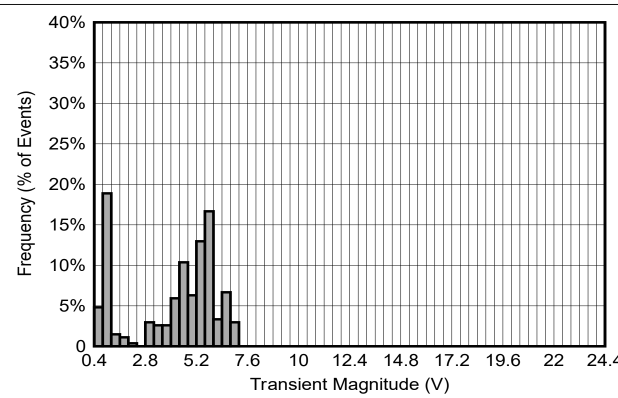


Figure 7-30. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 5.3MeV-cm^2 / mg, Output Low Condition

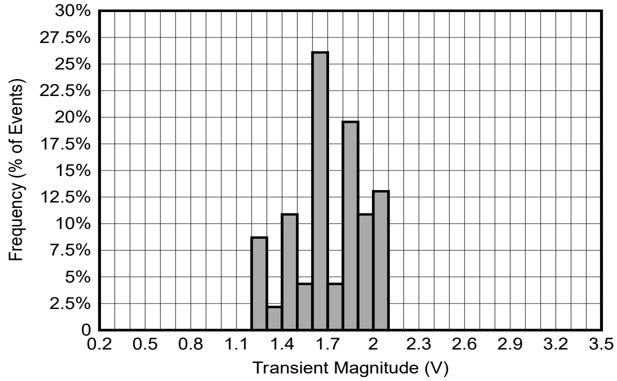


Figure 7-31. Transient Event Magnitude Histogram, 3.3V Supply, LET_{EFF} = 1.0MeV-cm^2 / mg, Output Low Condition

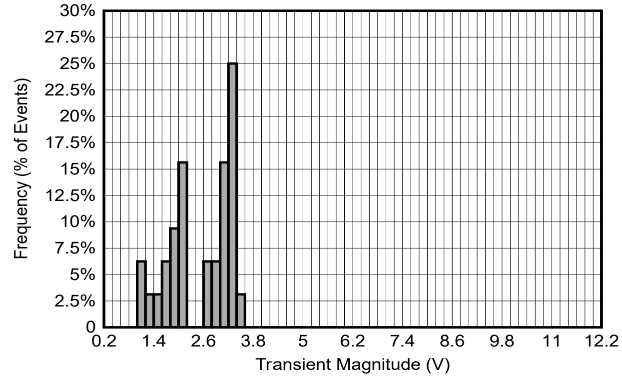


Figure 7-32. Transient Event Magnitude Histogram, 12V Supply, LET_{EFF} =1.0MeV-cm^2 / mg, Output Low Condition

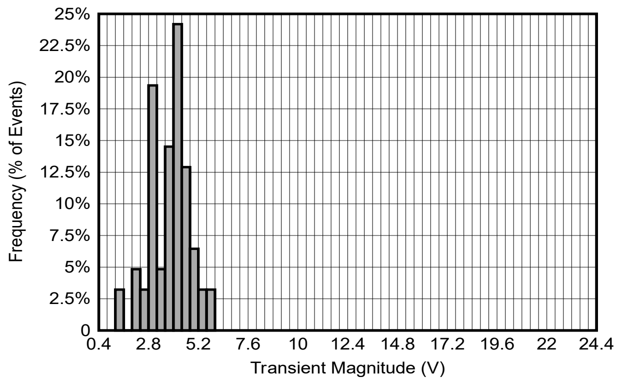


Figure 7-33. Transient Event Magnitude Histogram, 24V Supply, LET_{EFF} = 1.0MeV-cm^2 / mg, Output Low Condition

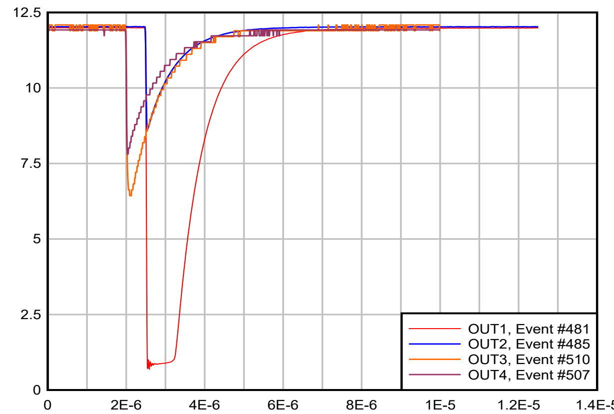


Figure 7-34. Typical Transient Waveforms, Run #91

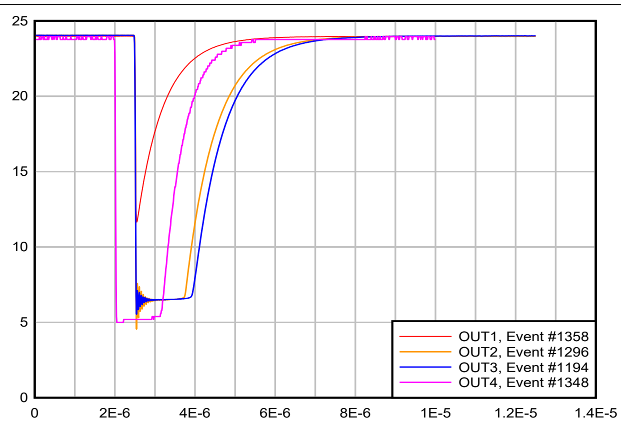


Figure 7-35. Typical Transient Waveforms, Run #97

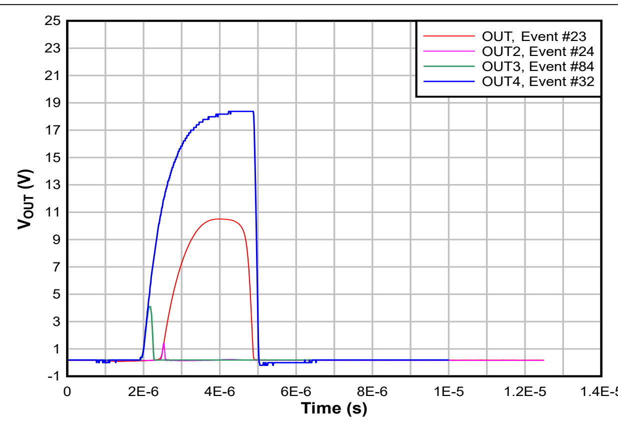


Figure 7-36. Typical Transient Waveforms, Run #99

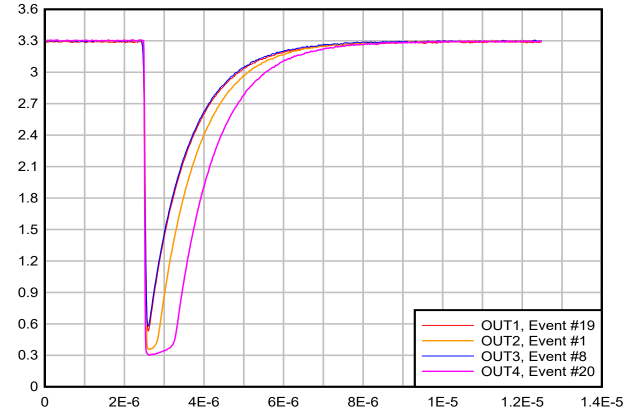


Figure 7-37. Typical Transient Waveform, Run#259

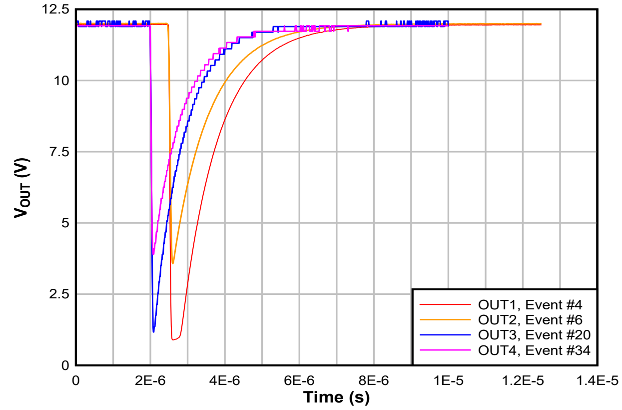


Figure 7-38. Typical Transient Waveform, Run#260

8 Confidence Interval Calculations

For conventional products where hundreds of failures are seen during a single exposure, one can determine the average failure rate of parts being tested in a heavy-ion beam as a function of fluence with high degree of certainty and reasonably tight standard deviation, and thus have a good deal of confidence that the calculated cross-section is accurate.

With radiation hardened parts however, determining the cross-section becomes more difficult since often few, or even, no failures are observed during an entire exposure. Determining the cross-section using an average failure rate with standard deviation is no longer a viable option, and the common practice of assuming a single error occurred at the conclusion of a null-result can end up in a greatly underestimated cross-section.

In cases where observed failures are rare or non-existent, the use of confidence intervals and the chi-squared distribution is indicated. The Chi-Squared distribution is particularly well-suited for the determination of a reliability level when the failures occur at a constant rate. In the case of SEE testing, where the ion events are random in time and position within the irradiation area, one expects a failure rate that is independent of time (presuming that parametric shifts induced by the total ionizing dose do not affect the failure rate), and thus the use of chi-squared statistical techniques is valid (since events are rare an exponential or Poisson distribution is usually used).

In a typical SEE experiment, the device-under-test (DUT) is exposed to a known, fixed fluence (ions/cm^2) while the DUT is monitored for failures. This is analogous to fixed-time reliability testing and, more specifically, time-terminated testing, where the reliability test is terminated after a fixed amount of time whether or not a failure has occurred (in the case of SEE tests fluence is substituted for time and hence it is a fixed fluence test [5]). Calculating a confidence interval specifically provides a range of values which is likely to contain the parameter of interest (the actual number of failures/fluence). Confidence intervals are constructed at a specific confidence level. For example, a 95% confidence level implies that if a given number of units were sampled numerous times and a confidence interval estimated for each test, the resulting set of confidence intervals would bracket the true population parameter in about 95% of the cases.

In order to estimate the cross-section from a null-result (no fails observed for a given fluence) with a confidence interval, we start with the standard reliability determination of lower-bound (minimum) mean-time-to-failure for fixed-time testing (an exponential distribution is assumed):

$$MTTF = \frac{2nT}{\chi^2_{2(d+1);100\left(1-\frac{\alpha}{2}\right)}} \tag{1}$$

Where *MTTF* is the minimum (lower-bound) mean-time-to-failure, *n* is the number of units tested (presuming each unit is tested under identical conditions) and *T*, is the test time, and χ^2 is the chi-square distribution evaluated at 100(1 – α / 2) confidence level and where *d* is the degrees-of-freedom (the number of failures observed). With slight modification for our purposes we invert the inequality and substitute *F* (fluence) in the place of *T*:

$$MFTF = \frac{2nF}{\chi^2_{2(d+1);100\left(1-\frac{\alpha}{2}\right)}} \tag{2}$$

Where now *MFTF* is mean-fluence-to-failure and *F* is the test fluence, and as before, χ^2 is the chi-square distribution evaluated at 100(1 – α / 2) confidence and where *d* is the degrees-of-freedom (the number of failures observed). The inverse relation between *MTTF* and failure rate is mirrored with the *MFTF*. Thus the upper-bound cross-section is obtained by inverting the *MFTF*:

$$\sigma = \frac{\chi^2_{2(d+1);100\left(1-\frac{\alpha}{2}\right)}}{2nF} \tag{3}$$

Assume that all tests are terminated at a total fluence of 10^6 ions/cm^2. Also assume there are a number of devices with very different performances that are tested under identical conditions. Assume a 95% confidence level (σ = 0.05). Note that as *d* increases from 0 events to 100 events the actual confidence interval becomes smaller, indicating that the range of values of the true value of the population parameter (in this case the cross-section) is approaching the mean value + 1 standard deviation. This makes sense when one considers that as more events are observed the statistics are improved such that uncertainty in the actual device performance is reduced.

Table 8-1. Experimental Example Calculation of MFTF and σ Using a 95% Confidence Interval

Degrees-of-Freedom (d)	2(d + 1)	χ^2 @ 95%	Calculated Cross Section (cm^2)		
			Upper-Bound @ 95% Confidence	Mean	Average + Standard Deviation
0	2	7.38	3.69E–06	0.00E+00	0.00E+00
1	4	11.14	5.57E–06	1.00E–06	2.00E–06
2	6	14.45	7.22E–06	2.00E–06	3.41E–06
3	8	17.53	8.77E–06	3.00E–06	4.73E–06
4	10	20.48	1.02E–05	4.00E–06	6.00E–06
5	12	23.34	1.17E–05	5.00E–06	7.24E–06
10	22	36.78	1.84E–05	1.00E–05	1.32E–05
50	102	131.84	6.59E–05	5.00E–05	5.71E–05
100	202	243.25	1.22E–04	1.00E–04	1.10E–04

9 Revision History

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