Radiation Report

SN54SLC8T245-SEP Single Event Effects Report

ABSTRACT

The purpose of this study is to characterize the effects of heavy-ion irradiation on the single-event latch-up (SEL) and single-event transient (SET) performance of the SN54SLC8T245-SEP, 8-bit dual-supply bus transceiver. Heavy-ions with an LET_{EFF} of 43 MeV-cm^2/mg were used to irradiate the devices with a fluence of 1 × 10^7 ions/cm^2 for SEL and 1 × 10^6 ions/cm^2 for SET. The results demonstrate that the SN54SLC8T245-SEP is SEL-free up to LET_{EFF} = 43 MeV-cm^2/mg at 125°C. SET characterization is presented and discussed for a variety of different operating conditions.

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1 Overview

The SN54SLC8T245-SEP device is an 8-bit noninverting bus transceiver that resolves voltage level mismatch between devices operating at the latest voltage nodes (0.7 V, 0.8 V, and 0.9 V) and devices operating at industry standard voltage nodes (1.8 V, 2.5 V, and 3.3 V). The device operates by using two independent power supply rails (V_{CCA} and V_{CCB}) that operate as low as 0.65 V. Data pins A1 through A8 are designed to track V_{CCA}, which accepts any supply voltage from 0.65 V to 3.6 V. Data pins B1 through B8 are designed to track V_{CCB}, which accepts any supply voltage from 0.65 V to 3.6 V.

Table 1-1. Overview Information[1]

DESCRIPTION	DEVICE INFORMATION
TI Part Number	SN54SLC8T245-SEP
MLS Number	SN54SLC8T245PWTSEP
Device Function	Radiation tolerant 8-bit dual-supply bus transceiver with configurable voltage translation
Technology	LBC7
Exposure Facility	Radiation Effects Facility, Cyclotron Institute, Texas A&M University
Heavy Ion Fluence per Run	1×10^6 – 1×10^7 ions/cm^2
Irradiation Temperature	125°C (for SEL testing)

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2 SEE Mechanisms

The primary single-event effect (SEE) events of interest in the SN54SLC8T245-SEP are the destructive single-event latch-up (SEL) and Single Event Transient (SET). From a risk or impact perspective, the occurrence of an SEL is potentially the most destructive SEE event and the biggest concern for space applications. The LBC7 process node was used for the SN54SLC8T245-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 SN54SLC8T245-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 3.6 V on V_{CCA} 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/cm^2 were used during the exposure at 125°C temperature.

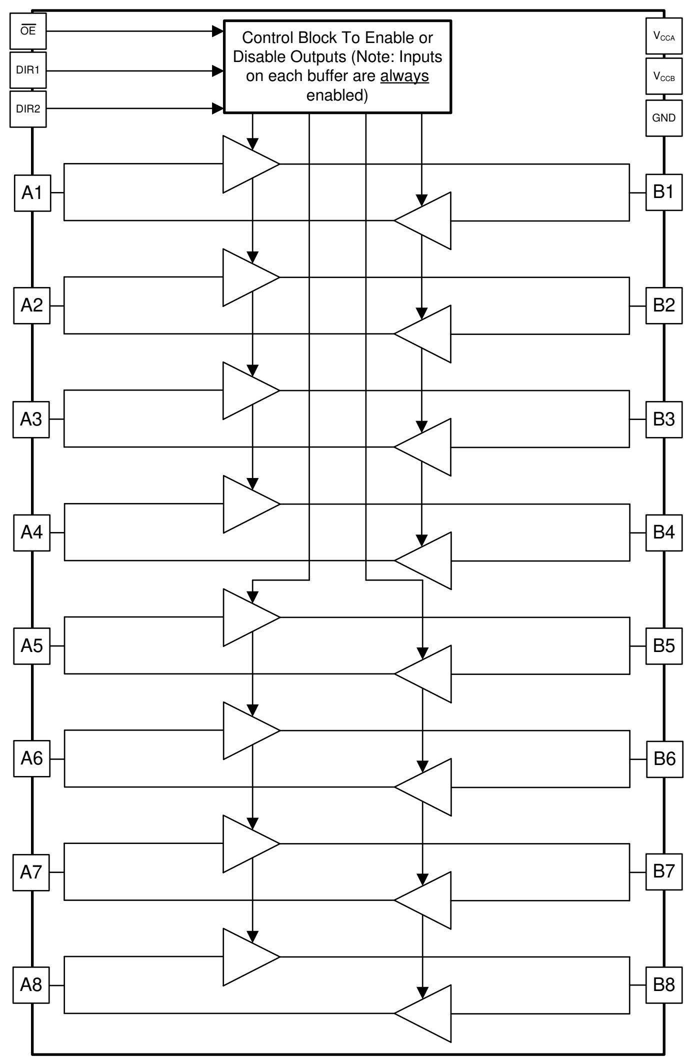

Figure 2-1. Functional Block Diagram of the SN54SLC8T245-SEP

3 Test Device and Test Board Information

The SN54SLC8T245-SEP is packaged in a 24-pin, TSSOP. Figure 3-1 shows the SN54SLC8T245-SEP pinout diagram and the package with the cap removed to reveal the die face for all heavy ion testing. Figure 3-2 and Figure 3-2 show the SN54SLC8T245-SEP bias diagrams.

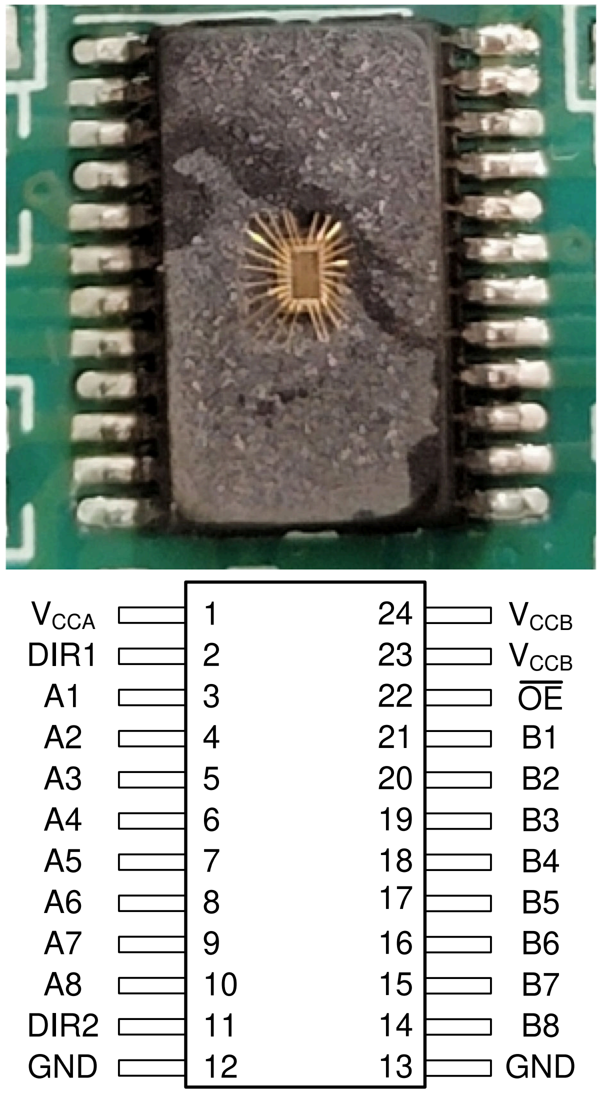

Figure 3-1. SN54SLC8T245-SEP Photograph and Pinout Diagram

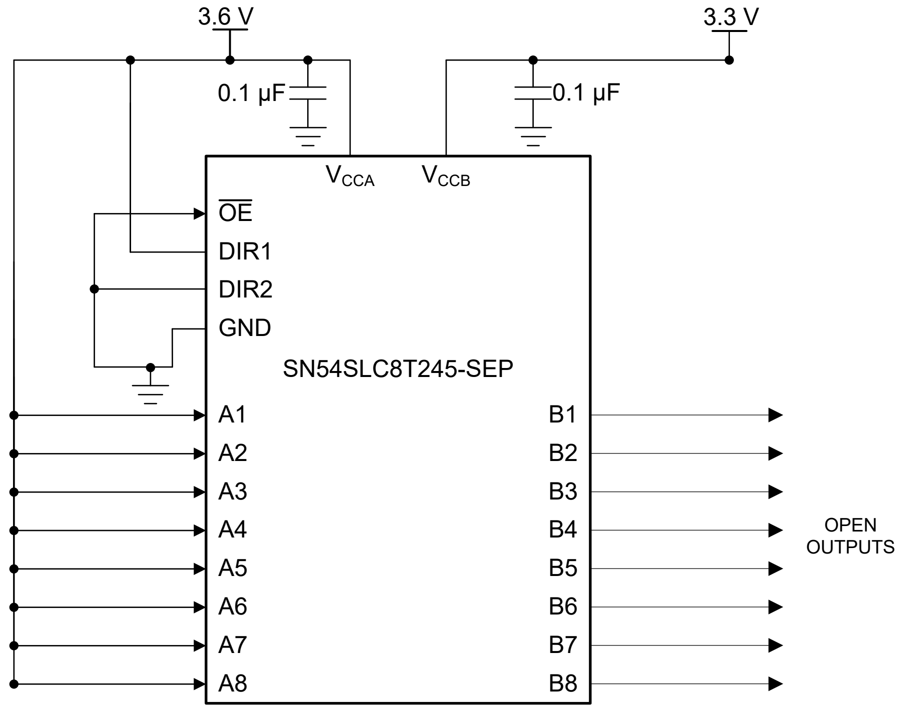

Figure 3-2. SN54SLC8T245-SEP SEL Bias Diagram

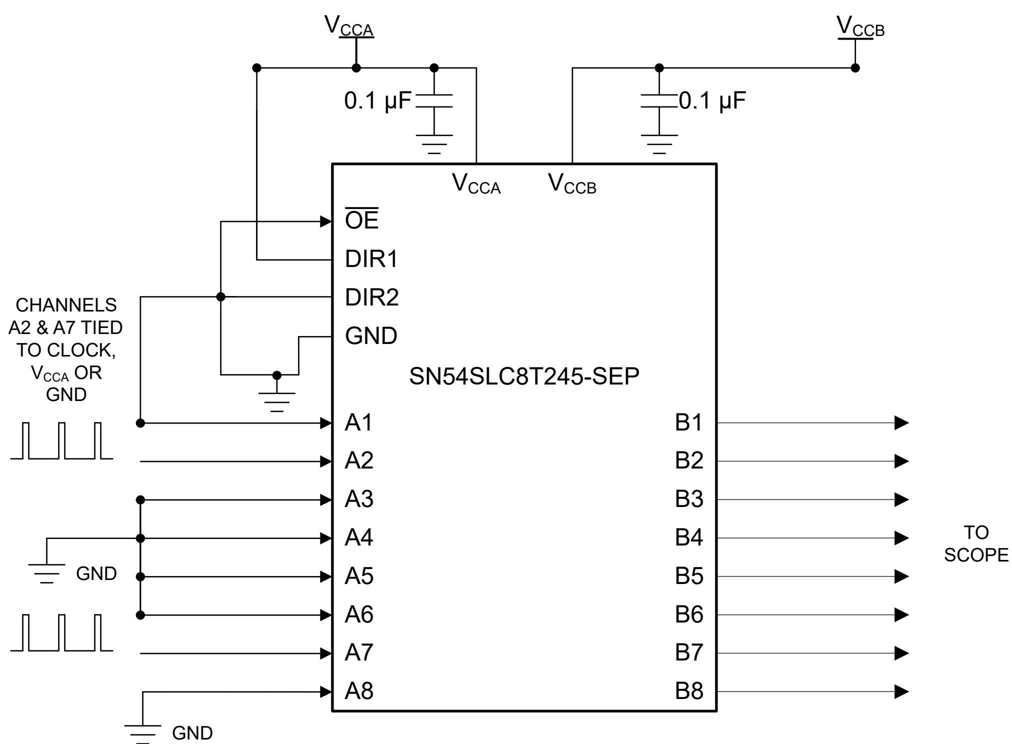

Figure 3-3. SN54SLC8T245-SEP SET Bias Diagram

4 Irradiation Facility and Setup

The heavy ion species used for the SEE studies on this product were provided and delivered by the TAMU Cyclotron Radiation Effects Facility [3] using a superconducting cyclotron and advanced electron cyclotron resonance (ECR) ion source. Ion beams are delivered with high uniformity over a 1-inch diameter circular cross sectional area for the in-air station. Uniformity is achieved by means of magnetic defocusing. The intensity of the beam is regulated over a broad range spanning several orders of magnitude. For the bulk of these studies, ion fluxes between 10^5 and 10^4 ions/s-cm^2 were used to provide heavy ion fluences between 10^6 and 10^7 ions/cm^2. For these experiments Silver (Ag) ions were used. Ion beam uniformity for all tests was in the range of 97% to 99%.

Figure 4-1 shows the top side of the SN54SLC8T245 test board used for the experiments at the TAMU facility. The board was configured using jumpers to achieve the bias diagrams outlined in Section 3. Although not visible in this photo, the beam port has a 1-mil Aramica window to allow in-air testing while maintaining the vacuum within the accelerator with only minor ion energy loss. All through-hole test points were soldered backwards for easy access of the signals while having enough room to change the angle of incidence and maintaining the 40-mm distance to the die. The in-air gap between the device and the ion beam port window was maintained at 40 mm for all runs.

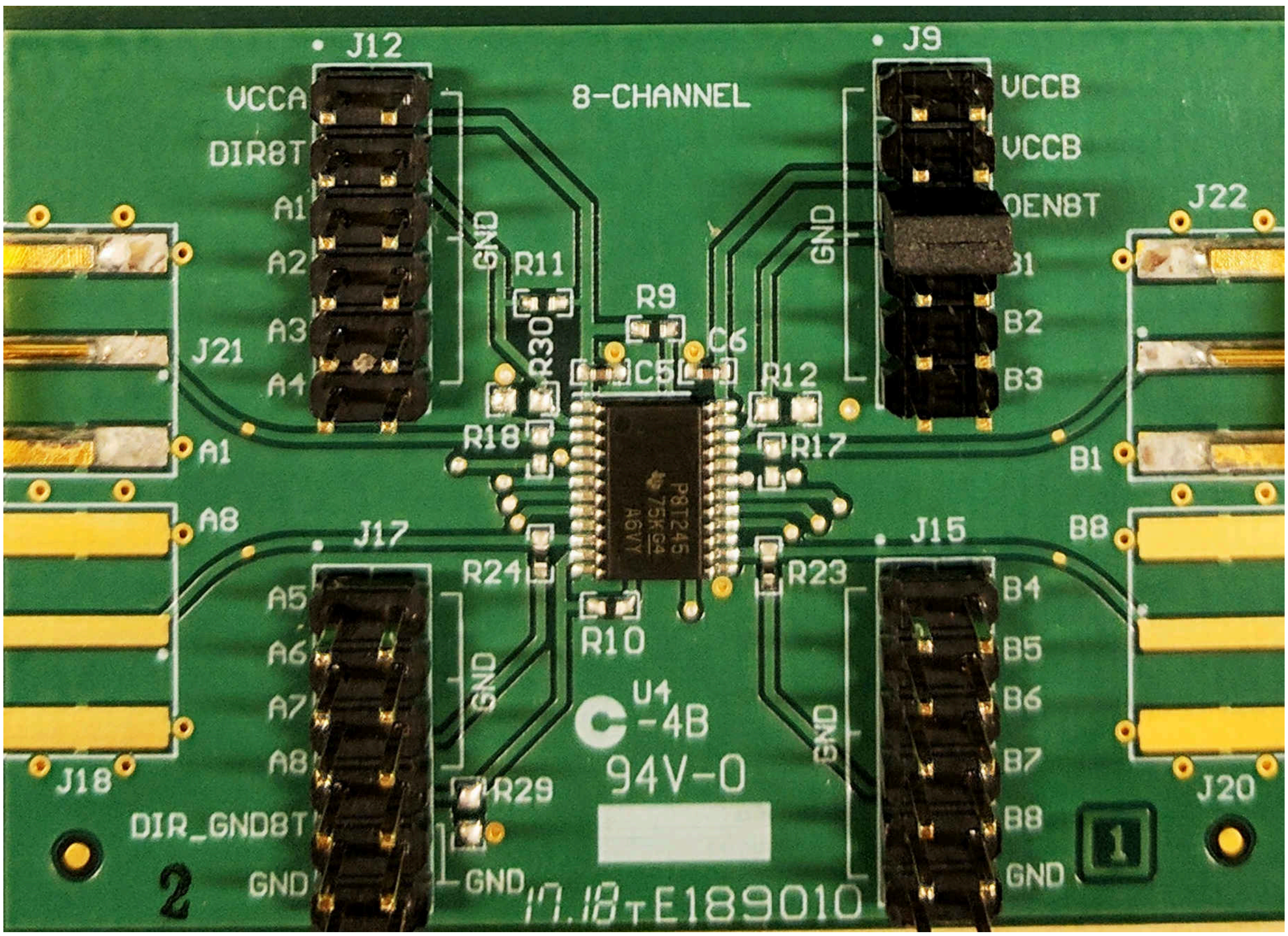

Figure 4-1. SN54SLC8T245-SEP Board (Top View)

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 K-type thermocouple attached as close to the IC as possible. The species used for the SEL testing was a silver (^{47}Ag) ion with an angle-of-incidence of 0° for an LET_{EFF} = 43 MeV-cm^2/mg. The kinetic energy in the vacuum for this ion is 1.634 GeV (15-MeV/amu line). A fluence of approximately 2 x 10^7 ions were used for the run. The V_{CCA} and V_{CCB} supply voltage is supplied externally onboard at the recommended maximum voltage setting of 3.6 V. Run duration to achieve this fluence was approximately 3 minutes. As provided in Table 5-1, no SEL events were observed during run time. Figure 5-1 shows a plot of the current versus time.

Table 5-1. SN54SLC8T245-SEP SEL Conditions Using^{47}Ag at an Angle-of-Incidence of 0°

RUN #	DISTANCE (mm)	TEMPERATURE (°C)	ION	ANGLE	FLUX (ions·cm^2/mg)	FLUENCE (# ions)	LET_{EFF} (MeV.cm^2/mg)
1	40	125	Ag	0°	1.00E+05	2.00E+07	43

No SEL events were observed, indicating that the SN54SLC8T245-SEP is SEL-immune at LET_{EFF} = 43 MeV-cm^2/mg and T = 125°C. Using the MFTF method described in *Single-Event Effects (SEE) Confidence Interval Calculations* application report, the upper-bound cross section (using a 95% confidence level) is calculated as:

$$\sigma SEL \leq 1.85 \times 10^{-7} \frac{cm^2}{device} \text{ for LETEFF } = \frac{43 \text{ MeV } \times cm^2}{mg} \text{ and T } = 125°C \quad (1)$$

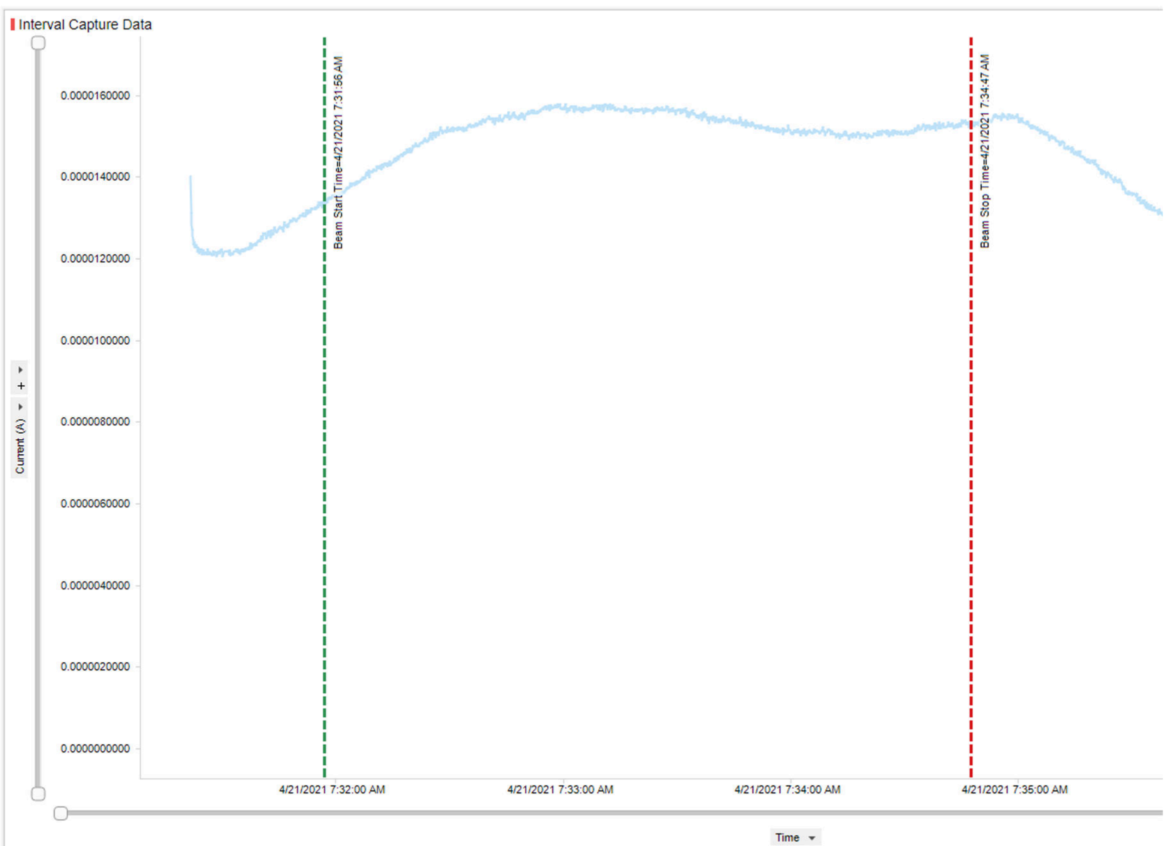

Figure 5-1. Current vs Time (I vs t) Data for Vs Current During SEL Run # 1

5.2 Single Event Transient (SET) Results

SETs are defined as heavy-ion-induced transients upsets on VOUT of the TPS7H1210-SEP. SET testing was performed at around 25°C. The species used for the SET testing was a Silver (^{109}Ag) ion with an angle-of incidence of 0° for an LETEFF = 43 MeV·cm^2 /mg. Flux of approximately 9.6× 10^3 to 1.1 × 10^4 ions/cm^2 ·s and a fluence of approximately 1 × 10^6 ions/cm^2 were used for the twelve SET runs.

Figure 3-2 shows the three main scenarios that were tested. The device was configured with clock signals ranging from 100 kHz to 5 MHz as inputs for channels A2 and A7.

Table 5-2. Summary of SN54SLC8T245-SEP SET Test Condition and Results

RUN #	LET_{EFF} (MeV·cm^2/mg)	ANGLE (°)	DISTANCE (mm)	FLUX (ions·cm^2/ mg)	FLUENCE (# ions)	UNIFORM	V_{CCA} (V)	V_{CCB} (V)	INPUT FREQ.	PULSE WIDTH	SAMPLING RATE	EVENT COUNT
1	43	0	40	9.7 × 10^3	1 × 10^6	99%	1 V	1 V	1 MHz	2 µs/div	200 MS/s	0
2	43	0	40	9.6 × 10^3	1 × 10^6	99%	1 V	1 V	1 MHz	10 µs/div	200 MS/s	0
3	43	0	40	1.1 × 10^4	1 × 10^6	99%	1 V	1 V	1 MHz	10 µs/div	200 MS/s	0
5	43	0	40	1.17 × 10^4	1 × 10^6	99%	3.3 V	3.3 V	5 MHz	1 µs/div	1 GS/s	0
6	43	0	40	1 × 10^4	1 × 10^6	98%	3.3 V	3.3 V	5 MHz	1 µs/div	1 GS/s	0
7	43	0	40	1 × 10^4	1 × 10^6	98%	1 V	1 V	5 MHz	1 µs/div	1 GS/s	0
8	43	0	40	1.09 × 10^4	1 × 10^6	98%	1.8 V	1.8 V	5 MHz	1 µs/div	1 GS/s	0
9	43	0	40	1.1 × 10^4	1 × 10^6	98%	3.3 V	1 V	5 MHz	1 µs/div	1 GS/s	0
10	43	0	40	1.1 × 10^4	1 × 10^6	98%	2.5 V	1 V	5 MHz	1 µs/div	1 GS/s	0
11	43	0	40	1.1 × 10^4	1 × 10^6	98%	1 V	3.3 V	5 MHz	1 µs/div	1 GS/s	0
12	43	0	40	1.08 × 10^4	1 × 10^6	97%	3 V	1 V	5 MHz	1 µs/div	1 GS/s	0
13	43	0	40	1.1 × 10^4	1 × 10^6	97%	3.3 V	3.3 V	100 kHz	50 µs/div	20 MS/s	0

Using the MFTF method described in *Single-Event Effects (SEE) Confidence Interval Calculations* application report, the upper-bound cross section (using a 95% confidence level) is calculated as:

$$\frac{\sigma\text{SET} \leq 3.69 \times 10^{-6}\ cm^2}{device} \text{ for LETEFF } = \frac{43\text{ MeV} \times cm^2}{mg} \text{ and T } = 25°\text{C} \quad (2)$$

5.3 Event Rate Calculations

Event rates were calculated for LEO (ISS) and GEO environments by combining CREME96 orbital integral flux estimations and simplified SEE cross-sections according to methods described in *Heavy Ion Orbital Environment Single-Event Effects Estimations* application report. We assume a minimum shielding configuration of 100 mils (2.54 mm) of aluminum, and *worst-week* solar activity (this is similar to a 99% upper bound for the environment). Table 5-3 and Table 5-4 provides the event rate calculation using the 95% upper-bounds for the SEL and the SET, respectively.

Note

It is important to note that This number is for reference since no SEL or SET events were observed.

Table 5-3. SEL Event Rate Calculations for Worst-Week LEO and GEO Orbits

Orbit Type	Onset LET_{EFF} (MeV-cm^2/mg)	CREME96 Integral FLUX (/day/cm^2)	σSAT (cm^2)	Event Rate (/day)	Event Rate (FIT)	MTBF (Years)
LEO (ISS)	43	6.40 × 10^{-4}	1.85 × 10^{-7}	1.18 × 10^{-10}	4.93 × 10^{-3}	2.31 × 10^7
GEO		2.17 × 10^{-3}		4.01 × 10^{-10}	1.67 × 10^{-2}	6.82 × 10^6

Table 5-4. SET Event Rate Calculations for Worst-Week LEO and GEO Orbits

Orbit Type	Onset LET_{EFF} ($MeV\text{-}cm^2/mg$)	CREME96 Integral FLUX ($/day/cm^2$)	σSAT (cm^2)	Event Rate (/day)	Event Rate (FIT)	MTBF (Years)
LEO (ISS)	43	6.40×10^{-4}	3.69×10^{-6}	2.36×10^{-9}	9.84×10^{-2}	1.16×10^{6}
GEO		2.17×10^{-3}		8.01×10^{-9}	3.34×10^{-1}	3.42×10^{5}

6 Summary

The purpose of this study was to characterize the effect of heavy-ion irradiation on the single-event effect (SEE) performance of the SN54SLC8T245-SEP 8-bit dual-supply bus transceiver. Heavy-ions with LETEFF = 43 MeV·cm^2 /mg were were used for the SEE characterization campaign. The SEE results demonstrated that the SN54SLC8T245-SEP is free of destructive SET events and SEL-free up to LETEFF = 43 MeV·cm^2 /mg and across the full electrical specifications. Transients at LETEFF = 43 MeV·cm^2 /mg are presented and discussed. CREME96-based worst-week event-rate calculations for LEO (ISS) and GEO orbits for the DSEE are presented for reference.

A References

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