Radiation Report

SN54SC245-SEP Single-Event Latch-Up (SEL) Radiation Report

ABSTRACT

The purpose of this study is to characterize the effects of heavy-ion irradiation on the single-event latch-up (SEL) performance of the SN54SC245-SEP, 1.2 V to 5.5 V octal bus transceiver. Heavy-ions with an LET_{EFF} of 43 MeV-cm^2 / mg were used to irradiate three production devices with a fluence of 1×10^7 ions / cm^2. The results demonstrate that the SN54SC245-SEP is SEL-free up to LET_{EFF} = 43 MeV-cm^2 / mg as 125°C.

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Trademarks

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1 Overview

The SN54SC245-SEP is a radiation-tolerant, 1.2 V to 5.5 V, octal bus transceivers with tri-state outputs. All eight channels are controlled by the direction (DIR) pin and output enable ($\overline{OE}$) pin. The output enable ($\overline{OE}$) controls all outputs in the device. When the $\overline{OE}$ pin is in the low state, the appropriate outputs are enabled as determined by the direction (DIR) pin . When the $\overline{OE}$ pin is in the high state, all outputs of the device are disabled. All disabled outputs are placed into the high-impedance state.

See the SN54SC245-SEP product page for more details. Overview Information lists device information.

Table 1-1. Overview Information

Description	Device Information
TI part number	SN54SC245-SEP
MLS number	SN54SC245MPWTSEP
Device function	Radiation-tolerant, 1.2-V to 5.5-V, octal bus transceivers with tri-state outputs
Technology	LBC9
Exposure facility	Facility for Rare Isotope Beams (FRIB) at Michigan State University (FRIB Single Event Effects [FSEE] Facility)
Heavy ion fluence per run	1×10^7 ions / cm^2
Irradiation temperature	125°C (for SEL testing)

2 Single-Event Effects (SEE) Mechanisms

The primary single-event effect (SEE) event of interest in the SN54SC245-SEP is the destructive single-event latch-up. 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. In mixed technologies such as the Linear BiCMOS (LBC9) process used for SN54SC245-SEP, the CMOS circuitry introduces a potential 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-substrate 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 SN54SC245-SEP did not exhibit SEL with heavy-ions up to an LET_{EFF} of 43 MeV-cm^2 / mg at a fluence of 1 × 10^7 ions / cm^2 and a chip temperature of 125°C.

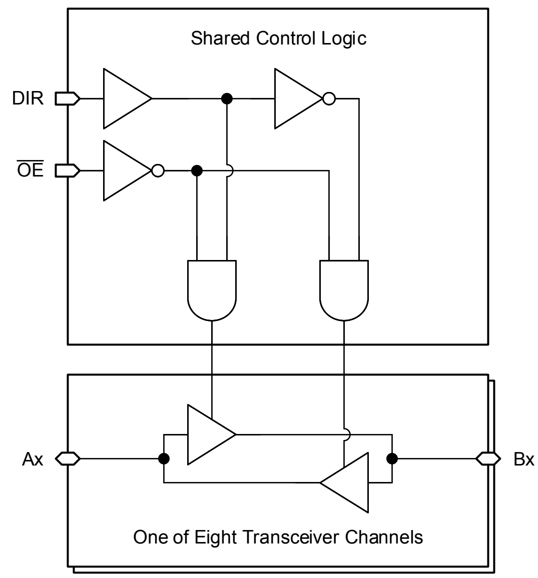

Figure 2-1. Functional Block Diagram of the SN54SC245-SEP

3 Test Device and Test Board Information

The SN54SC245-SEP is a packaged 20-pin, TSSOP plastic package as shown in the pinout diagram in Figure 3-1. Figure 3-2 shows the device with the package cap decapped to reveal the die for heavy ion testing. Figure 3-3 shows the evaluation board used for radiation testing. Figure 3-4 shows the bias diagram used for Single-Event Latch-up (SEL) testing.

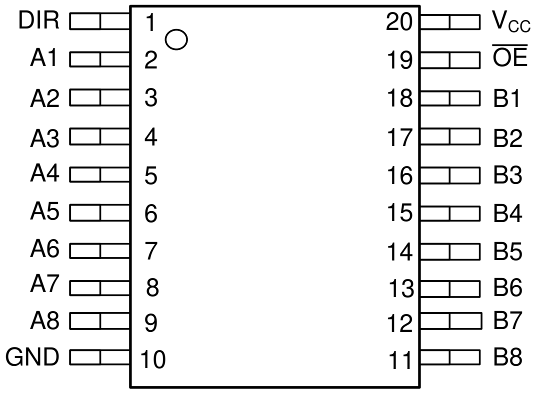

Figure 3-1. SN54SC245-SEP Pinout Diagram

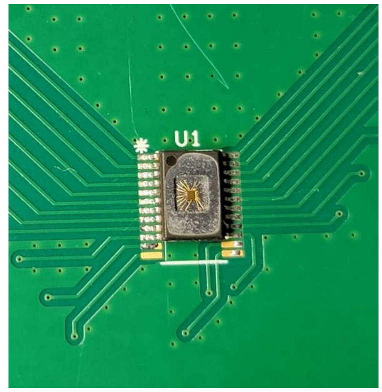

Figure 3-2. SN54SC245-SEP with Decapped Package

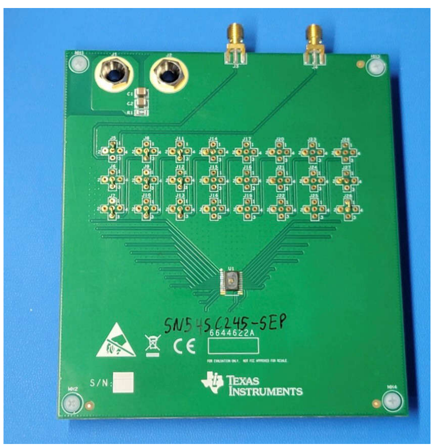

Figure 3-3. SN54SC245-SEP Evaluation Board (Top View)

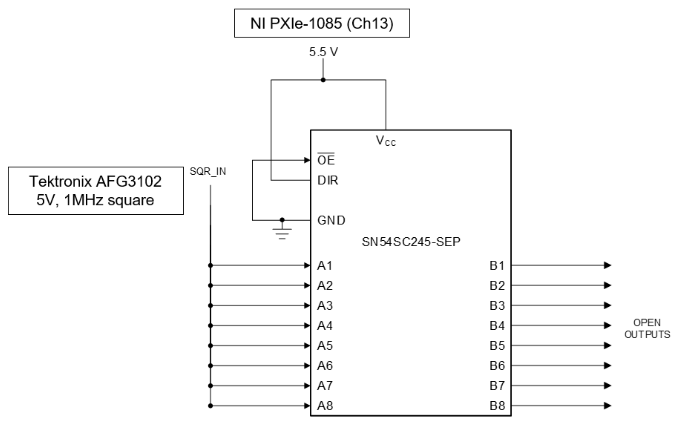

Figure 3-4. SN54SC245-SEP SEL Bias Diagram

Figure 3-5. SN54SC245-SEP Thermal Image for SEL

4 Irradiation Facility and Setup

The heavy ion species used for the SEE studies on this product were provided and delivered by the Facility for Rare Isotope Beams (FRIB) at Michigan State University – FRIB Single Event Effects (FSEE) Facility's linear accelerator. The FSEE Facility has a dedicated beamline built on the FRIB linac infrastructure with a user experimental station at the end of the FSEE beamline. Ion beams are delivered with high uniformity over a 1-inch diameter exposure area using a thin vacuum window. For this study, ion flux of 10^5 ions / s-cm^2 was used to provide heavy ion fluence of 1 × 10^7 ions / cm^2 using ^{129}Xe ion at a linac energy of 25 MeV / µ. Ion beam non-uniformity for all tests was 6.7%.

Figure 4-1 shows one of the three SN54SC245-SEP test board used for experiments at the MSU FSEE facility. The in-air gap between the device and the ion beam port window was maintained at 70 mm for all runs.

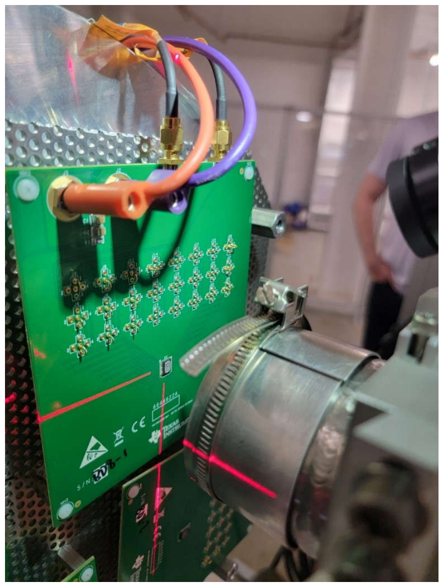

Figure 4-1. SN54SC245-SEP Evaluation Board at the MSU FRIB Facility

5 Results

5.1 SEL Results

During SEL characterization, the device was heated using forced hot air, maintaining device temperature at 125°C. A FLIR (FLIR ONE Pro LT) thermal camera was used to validate die temperature to make sure the device was being accurately heated (see Figure 3-5). The species used for SEL testing was a Xenon (^{129}Xe) ion at a linac energy of 25 MeV / μ with an angle-of-incidence of 0° for an LET_{EFF} of 43 MeV-cm^2 / mg. A fluence of approximately 1 × 10^7 ions / cm^2 were used for the runs.

The three devices were powered up and exposed to the heavy-ions using the maximum recommended supply voltage of 5.5 V with a National Instruments PXI Chassis PXIe-1085 and a 5-V, 1 MHz square wave input using a Tektronix AFG3102 function generator. The run duration to achieve this fluence was approximately two minutes. As listed in Table 5-1, no SEL events were observed during the nine runs, which indicates that the SN54SC245-SEP is SEL-free. Figure 5-1, Figure 5-2 , and Figure 5-3 show the plot of current versus time for runs one, four, and seven, respectively.

Table 5-1. Summary of SN54SC245-SEP Test Conditions and Results

Run Number	Unit Number	Distance (mm)	Temperature (°C)	Ion	Angle	FLUX (ions × cm^2 / mg)	Fluence (Number of ions)	LET_{EFF} (MeV × cm^2 / mg)	Did an SEL event occur?
1	1	70	121	Xe	0°	1.00E + 05	1.00E + 07	43	No
2	1	70	121	Xe	0°	1.00E + 05	1.00E + 07	43	No
3	1	70	121	Xe	0°	1.00E + 05	1.00E + 07	43	No
4	2	70	124	Xe	0°	1.00E + 05	1.00E + 07	43	No
5	2	70	124	Xe	0°	1.00E + 05	1.00E + 07	43	No
6	2	70	124	Xe	0°	1.00E + 05	1.00E + 07	43	No
7	3	70	126	Xe	0°	1.00E + 05	1.00E + 07	43	No
8	3	70	126	Xe	0°	1.00E + 05	1.00E + 07	43	No
9	3	70	126	Xe	0°	1.00E + 05	1.00E + 07	43	No

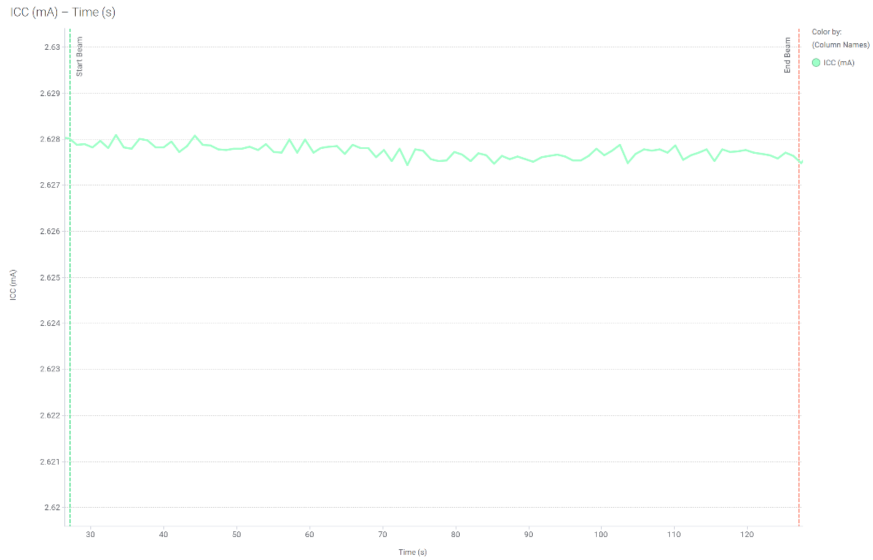

Figure 5-1. Current versus Time for Run Number 1 of the SN54SC245-SEP at T = 125°C

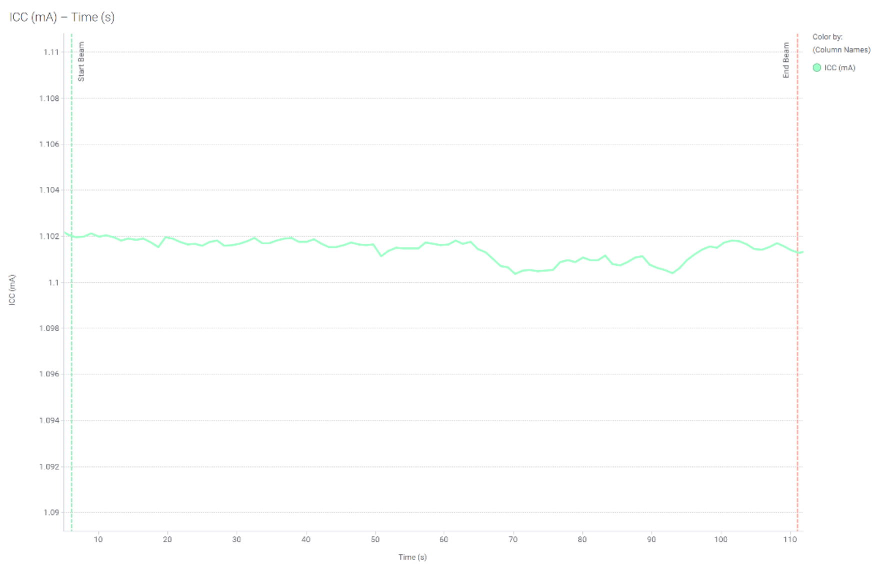

Figure 5-2. Current versus Time for Run Number 4 of the SN54SC245-SEP at T = 125°C

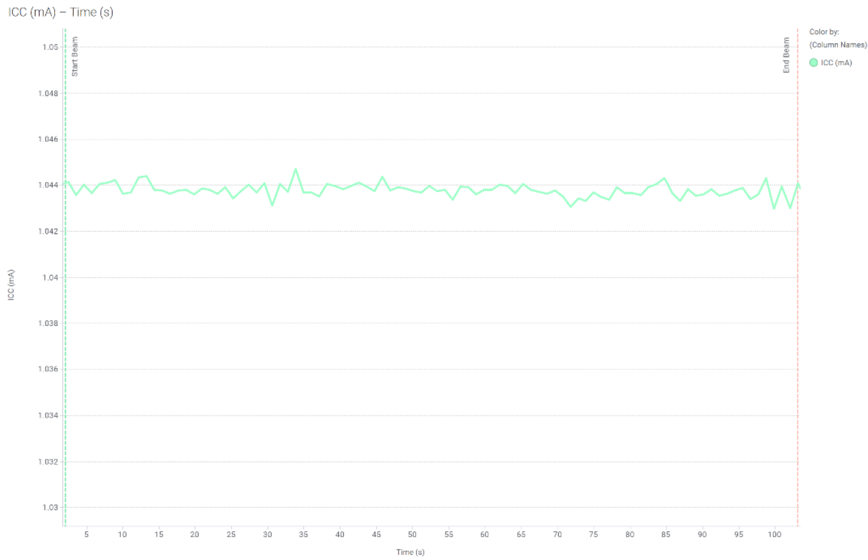

Figure 5-3. Current versus Time for Run Number 7 of the SN54SC245-SEP at T = 125°C

No SEL events were observed, which indicates that the SN54SC245-SEP is SEL-immune at LET_{EFF} = 43 MeV-cm^2 / mg and T = 125°C. Using the MFTF method described in Section 5.2, the upper-bound cross-section (using a 95% confidence level) is calculated as:

$$\sigma_{SEL} \leq 1.23 \times 10^{-7}\ \text{cm}^2/\ \text{device for}\ LET_{EFF} = 43\ \text{MeV-cm}^2\ /\ \text{mg and T} = 125°\text{C}. \quad (1)$$

5.2 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*. A minimum shielding configuration of 100 mils (2.54 mm) of aluminum and worst-week solar activity is assumed. (This is similar to a 99% upper bound for the environment). Table 5-2 lists the event rate calculations using the 95% upper-bounds for the SEL. It is important to note that this number is for reference since no SEL events were observed.

Table 5-2. SEL Event Rate Calculations for Worst-Week LEO and GEO Orbits

Orbit Type	Onset LET (MeV–cm^2 / mg)	CREME96 Integral Flux (/ day–cm^2)	σ_{SAT} (cm^2)	Event Rate (/ day)	Event Rate (FIT)	MTBE (years)
LEO(ISS)	43	6.40×10^{-4}	1.23×10^{-7}	7.87×10^{-11}	3.28×10^{-3}	3.48×10^{7}
GEO		2.17×10^{-3}		2.67×10^{-10}	1.11×10^{-2}	1.03×10^{7}

MTBE is the mean-time-between-events in years at the given event rates. These rates clearly demonstrate the SEE robustness of the SN54SC245-SEP in two harshly conservative space environments. Customers using the SN54SC245-SEP must only use the above estimations as a rough guide and TI recommends performing event rate calculations based on specific mission orbital and shielding parameters to determine if the product satisfies the reliability requirements for the specific mission.

6 Summary

The purpose of this study was to characterize the effects of heavy-ion irradiation on the single-event latch-up (SEL) performance of the SN54SC245-SEP, a radiation-tolerant 1.2-V to 5.5-V octal bus transceivers with tri-state outputs. Heavy-ions with an LET_{EFF} of 43 MeV-cm^2 / mg were used for the SEE characterization. The SEE results demonstrated that the SN54SC245-SEP is SEL-free up to LET_{EFF} = 43 MeV × cm^2 / mg and across the full electrical specifications. CREME96-based worst-week event-rate calculations for LEO (ISS) and GEO orbits for the DSEE are shown for reference.

7 References

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