Radiation Report

SN54SC4T08-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 SN54SC4T08-SEP, a four-channel, two-input positive AND gate with logic-level shifter. 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 SN54SC4T08-SEP is SEL-free up to LET_{EFF} = 43 MeV-cm^2 / mg at 125°C.

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1 Overview

SN54SC4T08-SEP contains four independent 2- input AND Gates . Each gate performs the Boolean function Y = A × B in positive logic. The output level is referenced to the supply voltage (VCC) and supports 1.2-V, 1.8-V, 2.5-V, 3.3-V, and 5-V CMOS levels.

The input is designed with a lower threshold circuit to support up translation for lower voltage CMOS inputs (for example 1.2 V input to 1.8 V output or 1.8 V input to 3.3 V output). Additionally, the 5-V tolerant input pins enable down translation (for example, 3.3 V to 2.5 V output).

Table 1-1. Overview Information[1]

Description	Device Information
TI Part Number	SN54SC4T08-SEP
MLS Number	SN54SC4T08MPWTSEP
Device Function	Radiation-tolerant, 4-channel, 2-input positive AND gate with logic-level shifter
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)

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2 Single-Event Effects (SEE)

The primary single-event effect (SEE) event of interest in the SN54SC4T08-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 SN54SC4T08-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 SN54SC4T08-SEP exhibited no 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.

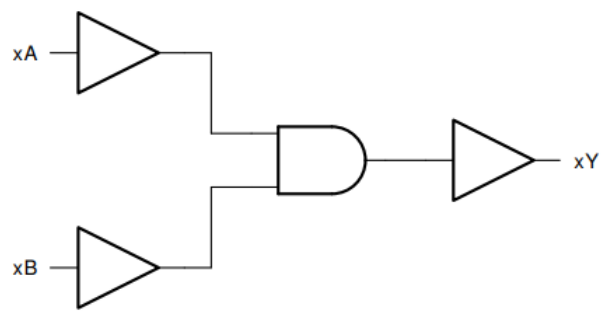

Figure 2-1. Functional Block Diagram of SN54SC4T08-SEP

3 Test Device and Test Board Information

The SN54SC4T08-SEP is a packaged 14-pin, TSSOP plastic package 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.

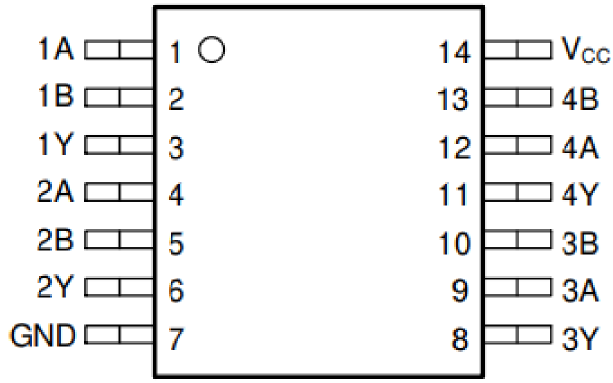

Figure 3-1. SN54SC4T08-SEP Pinout Diagram

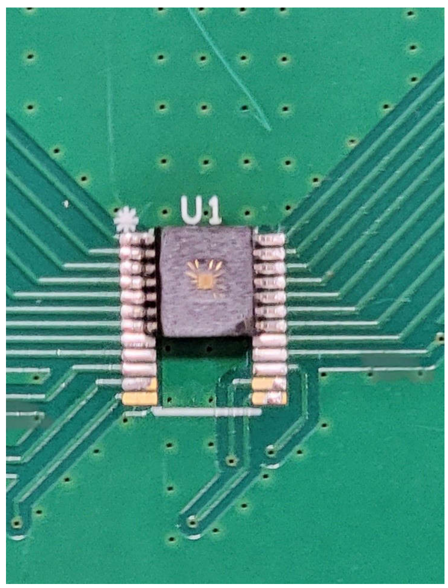

Figure 3-2. Photo of SN54SC4T08-SEP Package Decapped

Figure 3-3 shows the evaluation board used for radiation testing. Figure 3-4 shows the bias diagram used for SEL testing.

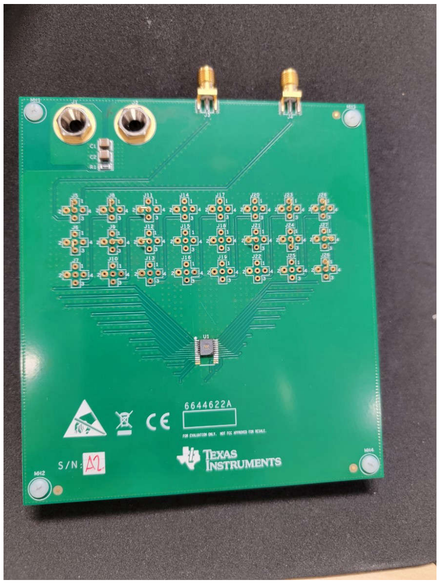

Figure 3-3. SN54SC4T08-SEP Evaluation Board Top View

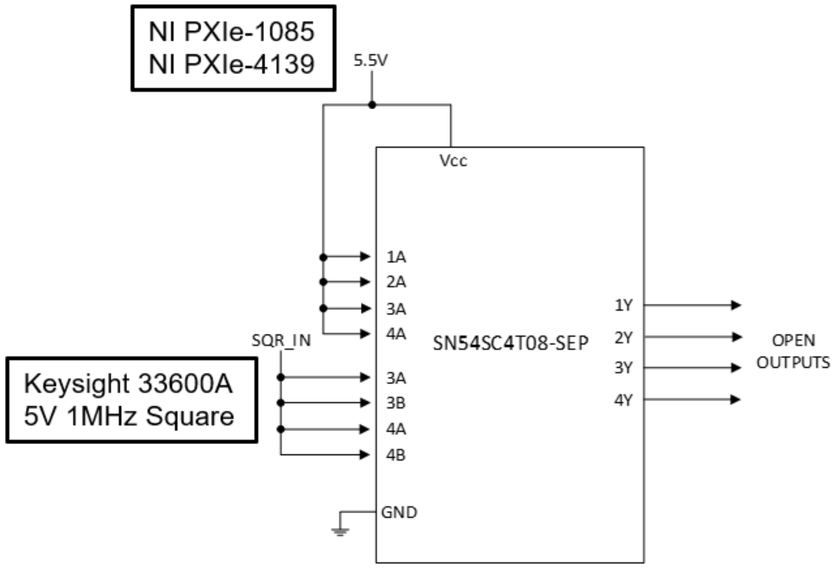

Figure 3-4. SN54SC4T08-SEP SEL Bias Diagram

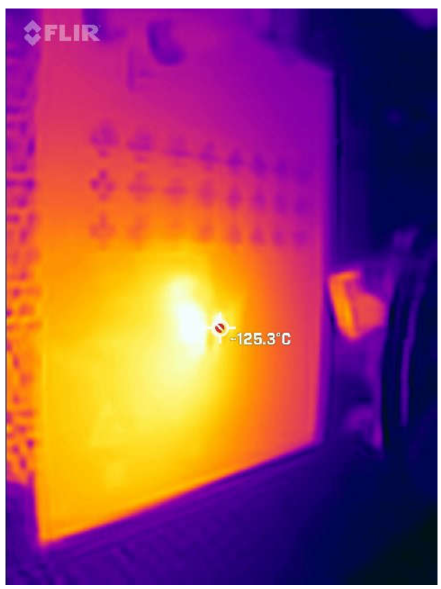

Figure 3-5. SN54SC4T08-SEP Thermal Image for SEL

4 Irradiation Facility and Setup

The heavy ion species used for the SEE studies on this product were provide 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 between 5.1% to 6.7%.

Figure 4-1 shows one of the three SN54SC4T08-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. SN54SC4T08-SEP Evaluation Board at the MSU FSEE Facility

5 Results

5.1 SEL Results

During SEL characterization, the device was heated using forced hot air, maintaining IC temperature at 125°C. A FLIR (FLIR ONE Pro LT) thermal camera was used to validate die temperature to ensure 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 using 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 SN54SC4T08-SEP is SEL-free. Figure 5-1, Figure 5-2, and Figure 5-3 show the plot of current versus time for run numbers 1, 4, and 7, respectively.

Table 5-1. Summary of SN54SC4T08-SEP Test Conditions and Results

Run Number	Unit Number	Ion	Distance (mm)	Angle	Temperature (°C)	LET_{EFF} (MeV × cm^2 / mg)	Flux (ions × cm^2 / mg)	Fluence (ions)	Did an SEL event occur?
1	1	Xe	70	0°	126	43	1.0E+05	1.0E+07	No
2	1	Xe	70	0°	126	43	1.0E+05	1.0E+07	No
3	1	Xe	70	0°	126	43	1.0E+05	1.0E+07	No
4	2	Xe	70	0°	125	43	1.0E+05	1.0E+07	No
5	2	Xe	70	0°	125	43	1.0E+05	1.0E+07	No
6	2	Xe	70	0°	125	43	1.0E+05	1.0E+07	No
7	3	Xe	70	0°	125	43	1.0E+05	1.0E+07	No
8	3	Xe	70	0°	125	43	1.0E+05	1.0E+07	No
9	3	Xe	70	0°	125	43	1.0E+05	1.0E+07	No

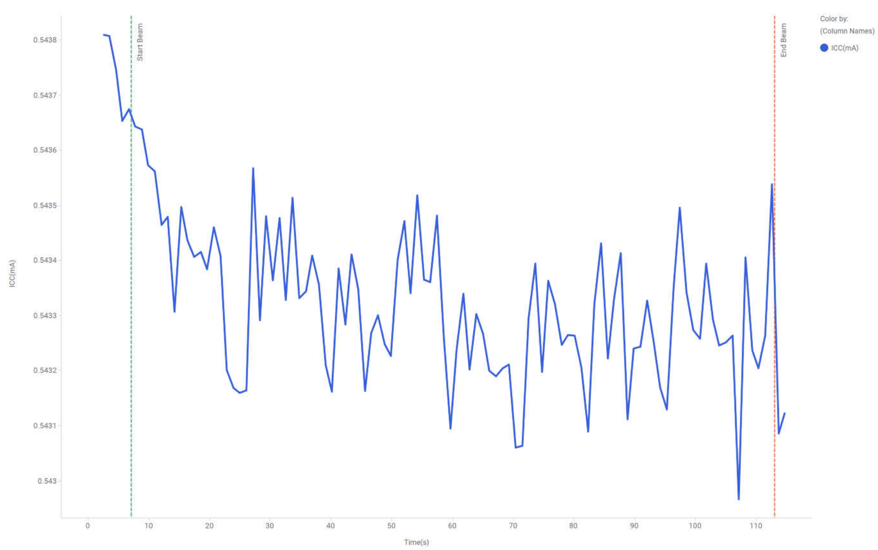

Figure 5-1. Current versus Time for Run 1 of the SN54SC4T08-SEP at T = 125°C

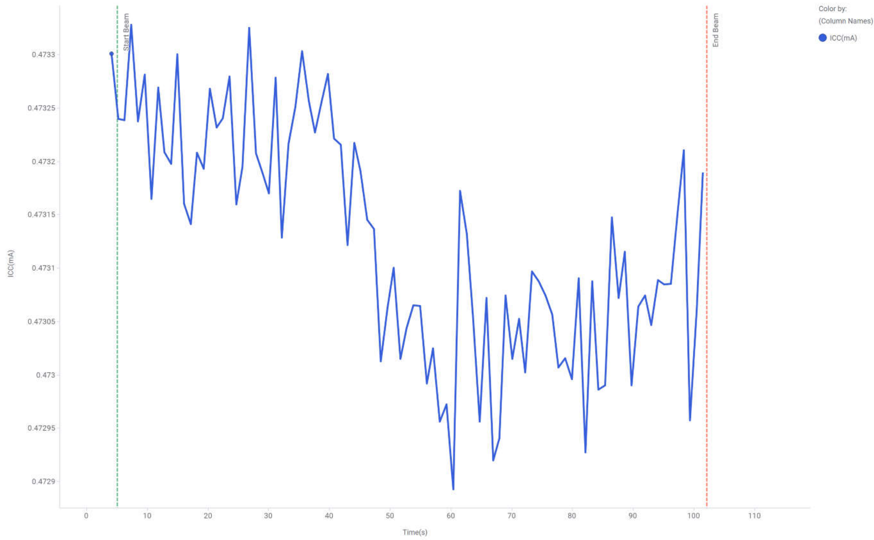

Figure 5-2. Current versus Time for Run 4 of the SN54SC4T08-SEP at T = 125°C

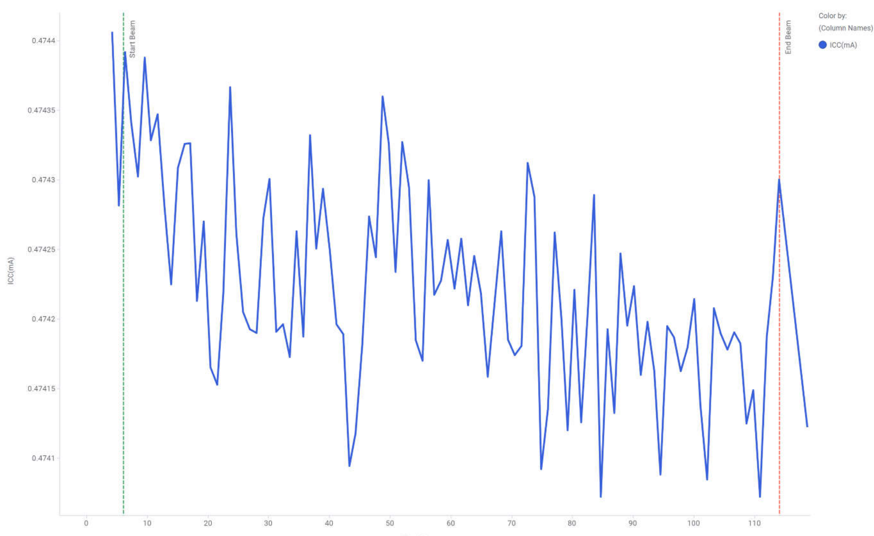

Figure 5-3. Current versus Time for Run 7 of the SN54SC4T08-SEP at T = 125°C

Using the MFTF method described in Single-Event Effects (SEE) Confidence Internal Calculations application report, 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* application report. 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) is assumed. It is important to note that this number is for reference since no events were observed.

Table 5-2. 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}	1.23×10^{-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}

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 SN54SC4T08-SEP, a radiation-tolerant, four-channel two-input positive AND gate with logic-level shifter. Heavy-ions with an LET_{EFF} of 43 MeV-cm^2 / mg were used for the SEE characterization. The SEE results demonstrated that the SN54SC4T08-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 presented for reference.

7 References

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