Radiation Report

TMUX182-SEP Single-Event Effects (SEE) Radiation Report

ABSTRACT

The purpose of this study is to characterize the single-event effects (SEE) performance due to heavy-ion irradiation of the TMUX182-SEP. SEE performance was verified at minimum (5V) and maximum (±6V) for dual-rail operating condition and maximum (15V) for single-rail operating condition. Heavy-ions with an LET_{EFF} of 47MeV-cm^2/mg were used to irradiate five production devices with a fluence of 1×10^7 ions/cm^2. The results demonstrate that the TMUX182-SEP is SEL-free up to LET_{EFF} = 47MeV-cm^2/mg as 125°C. SET performance at minimum and maximum operating voltages saw excursions ≥|5%| trigger up to fluence 1×10^7 ions/cm^2, as shown and discussed in this report.

Table of Contents

Trademarks

National Instruments™ is a trademark of National Instruments.
All trademarks are the property of their respective owners.

1 Overview

The TMUX182-SEP is a radiation-tolerant, general purpose complementary metal-oxide semiconductor (CMOS) multiplexer (MUX). The device works with a single supply (5V to 15V), dual supplies (up to ±6V), or asymmetric supplies (such as VDD = 6V, VSS = –3V). The wide supply voltage range allows the devices to be used in a broad array of applications in space.

The TMUX182-SEP supports bidirectional analog signals on the source (Sx) and drain (Dx) pins ranging from VSS to VDD. All logic inputs have 1.8V logic-compatible thresholds, which is compatible for both TTL and CMOS logic when operating with a valid supply voltage.

For more information, see the TMUX182-SEP product page.

Table 1-1. Overview Information

Description	Device Information
TI Part Number	TMUX182-SEP
Orderable Part Number	TMUX182MDYYTSEP
VID Number	V62/26609-01XE
Device Function	Radiation Tolerant 15V, 8:1, 1-Channel Multiplexer with 1.8V Logic
Technology	LBC9
Exposure Facility (SEL)	Facility for Rare Isotope Beams (FRIB), K500 Cyclotron (KSEE), Michigan State University
Heavy Ion Fluence per Run	1×10^7 ions/cm^2
Irradiation Temperature	25°C (for SET testing) and 125°C (for SEL testing)

2 Single-Event Effects (SEE)

The primary single-event effect (SEE) event of interest in the TMUX182-SEP is the destructive single-event latch-up (SEL). 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 Bi-CMOS (LBC9) process used for TMUX182-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 TMUX182-SEP exhibited no SEL with heavy-ions up to an LET_{EFF} of 47MeV-cm^2/mg at a fluence of 1×10^7 ions/cm^2 and a chip temperature of 125°C.

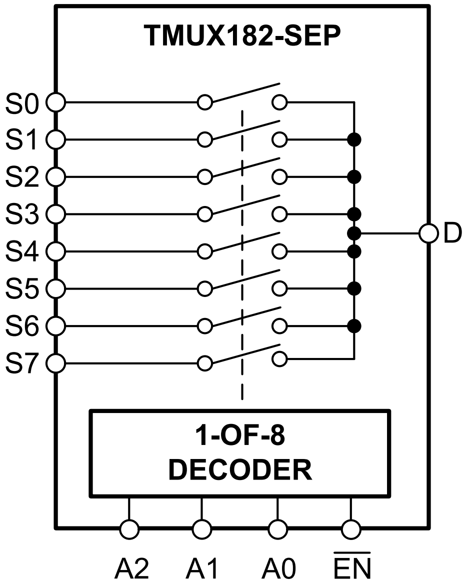
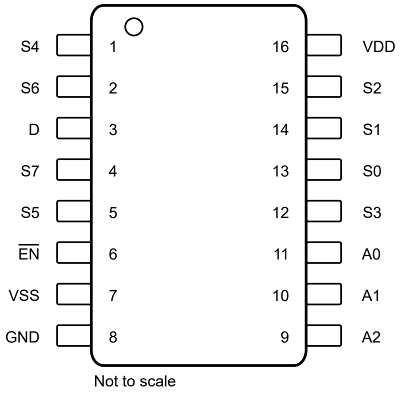


Figure 2-1. Functional Block Diagram of the TMUX182-SEP

3 Test Device and Test Board Information

The TMUX182-SEP is a packaged 16-pin DYY, SOT-23-THN 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 3-3 shows the evaluation board used for single-event effects. Figure 3-4 and Figure 3-5 show the bias diagrams used for SEL testing. Figure 3-6 and Figure 3-7 show the bias diagrams used for single-event transient (SET) testing.



Not to scale

Figure 3-1. TMUX182-SEP Pinout Diagram

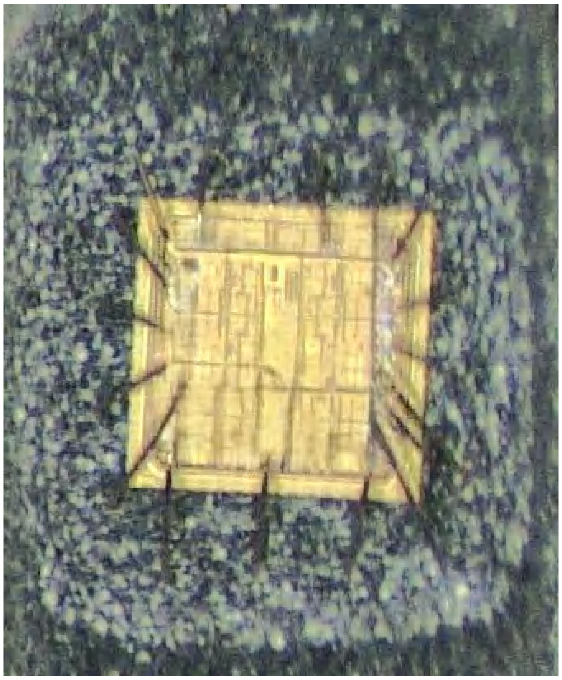


Figure 3-2. Photo of TMUX182-SEP Package Decapped

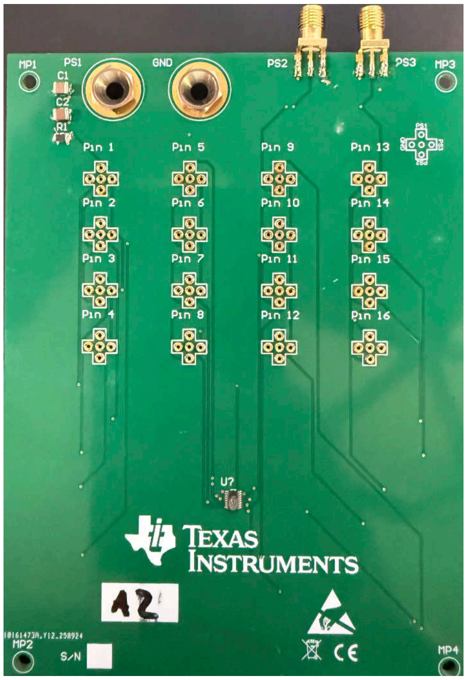


Figure 3-3. TMUX182-SEP Evaluation Board (Top View) for SEL Testing

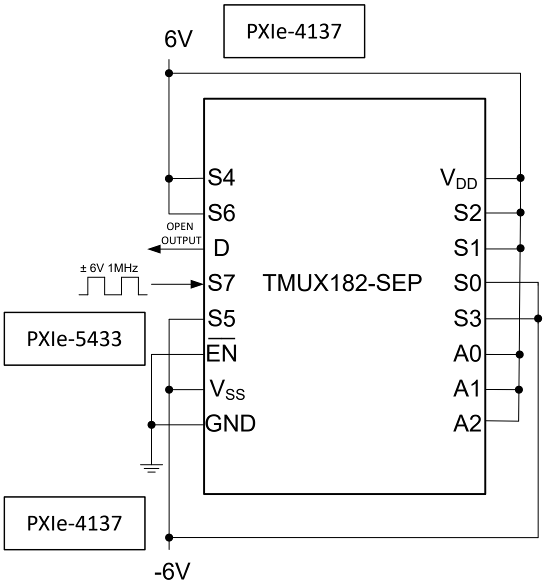


Figure 3-4. TMUX182-SEP SEL Bias 1 Diagram

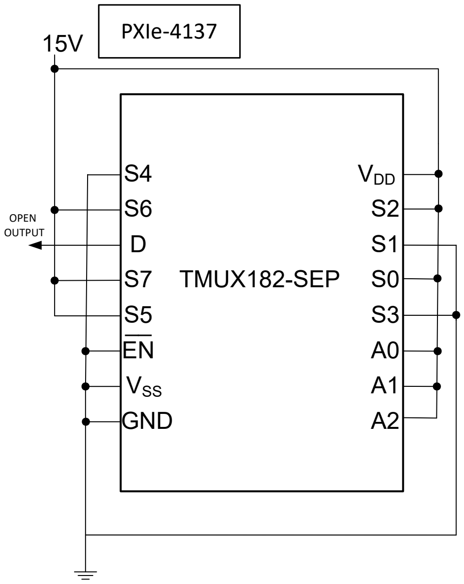


Figure 3-5. TMUX182-SEP SEL Bias 2 Diagram

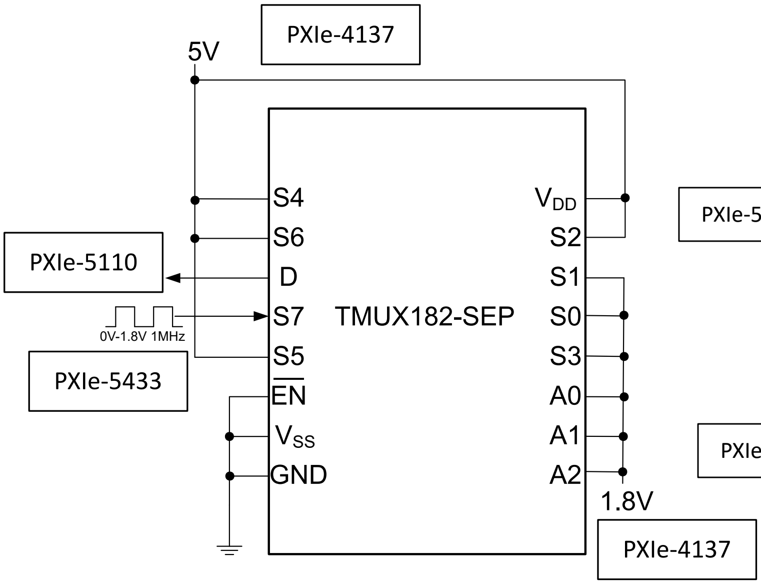


Figure 3-6. TMUX182-SEP SET Bias 1 Diagram

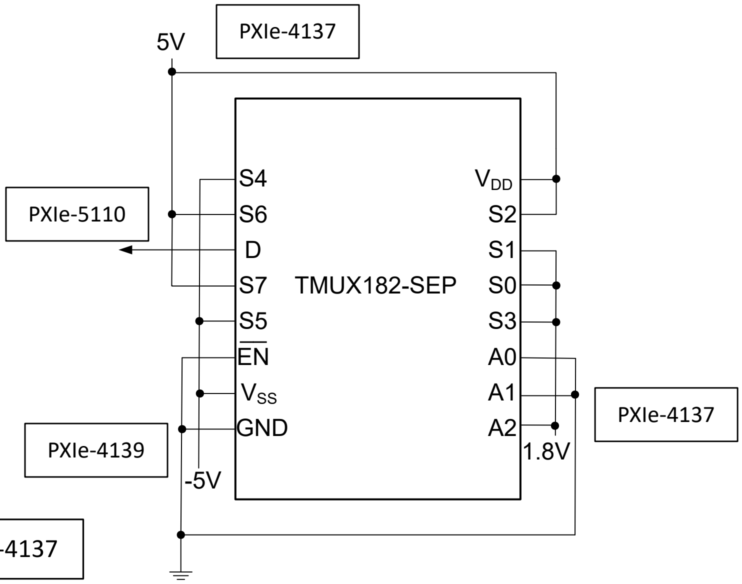


Figure 3-7. TMUX182-SEP SET Bias 2 Diagram

4 Irradiation Facility and Setup

The heavy-ion species used for the SEE studies on this product were provided and delivered by the MSU Cyclotron Radiation Effects Facility using a superconducting cyclotron and an advanced electron cyclotron resonance (ECR) ion source. At the fluxes used, ion beams had good flux stability and high irradiation uniformity over a 1-in diameter circular cross-sectional area for the in-air station. Uniformity is achieved by magnetic defocusing. The flux of the beam is regulated over a broad range spanning several orders of magnitude. For this study, ion flux of 1×10^5 ions/cm^2-s were used to provide heavy-ion fluences of approximately 1×10^7 ions/cm^2 for SEL testing. For the experiments conducted on this report, ^{109}Ag ions at angle of incidence of 0° for an LETEFF of 47MeV × cm^2/mg were used. The total kinetic energy of ^{109}Ag in the vacuum is 2.125GeV (19.5 MeV/nucleon). Ion uniformity for these experiments was 91.88%.

Figure 4-1 shows one of the four TMUX182-SEP test boards used for experiments at the MSU facility. The in-air gap between the device and the ion beam port window was maintained at 50mm for all runs.

Figure 4-1. TMUX182-SEP Evaluation Board at the MSU Facility

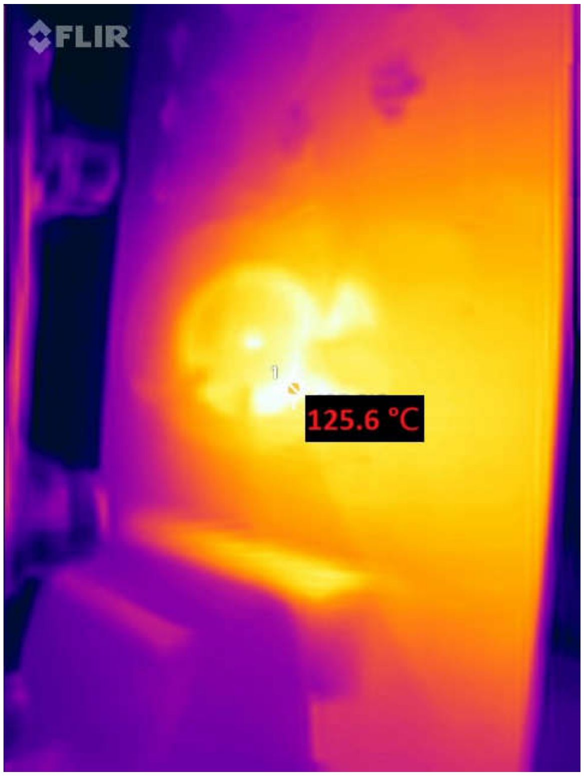


Figure 4-2. TMUX182-SEP Thermal Image for SEL

5 Results

5.1 Single-Event Latch-up (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 accurately heated (see Figure 4-2). The species used for SEL testing was a Silver (^{109}Ag) ion at 19.5MeV/μ with an angle of incidence of 0° for an LET_{EFF} of 47MeV-cm^2/mg. A fluence of approximately 1×10^7 ions/cm^2 was used for each run.

For Bias 1, the three devices were powered up and exposed to the heavy-ions using the maximum recommended supply voltage of ±6V using a National Instruments™ PXI Chassis PXIe-4137 on VDD and VSS. The bias was configured to select signal S7 as an output. A ±6V, 1MHz square wave on S7 was generated by using a National Instruments PXI Chassis PXIe-5433 function generator. The run duration to achieve this fluence was approximately 100 seconds. As listed in Table 5-1, no SEL events were observed during the ten runs, indicating that the TMUX182-SEP is SEL-free. Figure 5-1 shows the plots of current versus time for run one.

For Bias 2, the three devices were powered up and exposed to the heavy-ions using the maximum recommended supply voltage of 15V using a National Instruments PXI Chassis PXIe-4137 on VDD. The bias was configured to select signal S7 as an output. S7 was connected to VDD. As listed in Table 5-2, no SEL events were observed during the ten runs, indicating that the TMUX182-SEP is SEL-free. Figure 5-2 shows the plots of current versus time for run eleven.

Table 5-1. Summary of TMUX182-SEP SEL Bias 1 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	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
2	1	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
3	1	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
4	2	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
5	2	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
6	2	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
7	3	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
8	3	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
9	3	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
10	3	50	125	Ag	0°	1.00E+05	1.50E+07	47	No

Table 5-2. Summary of TMUX182-SEP SEL Bias 2 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?
11	4	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
12	4	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
13	4	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
14	5	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
15	5	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
16	5	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
17	6	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
18	6	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
19	6	50	125	Ag	0°	1.00E+05	1.00E+07	47	No
20	6	50	125	Ag	0°	1.00E+05	1.50E+07	47	No

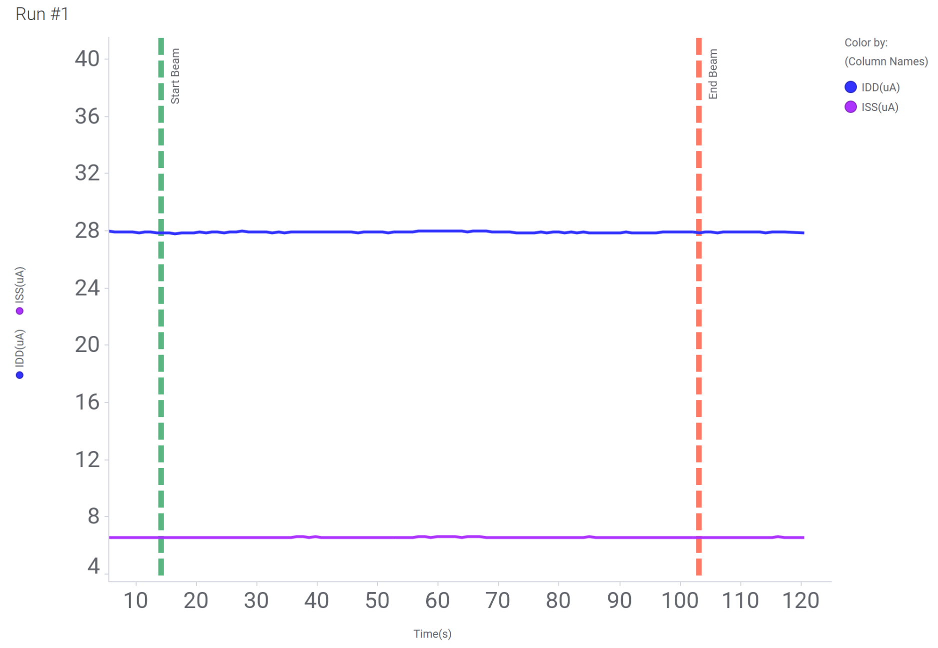


Figure 5-1. Current (µA) vs Time (s) for Run 1 of the TMUX182-SEP Bias 1 at T = 125°C

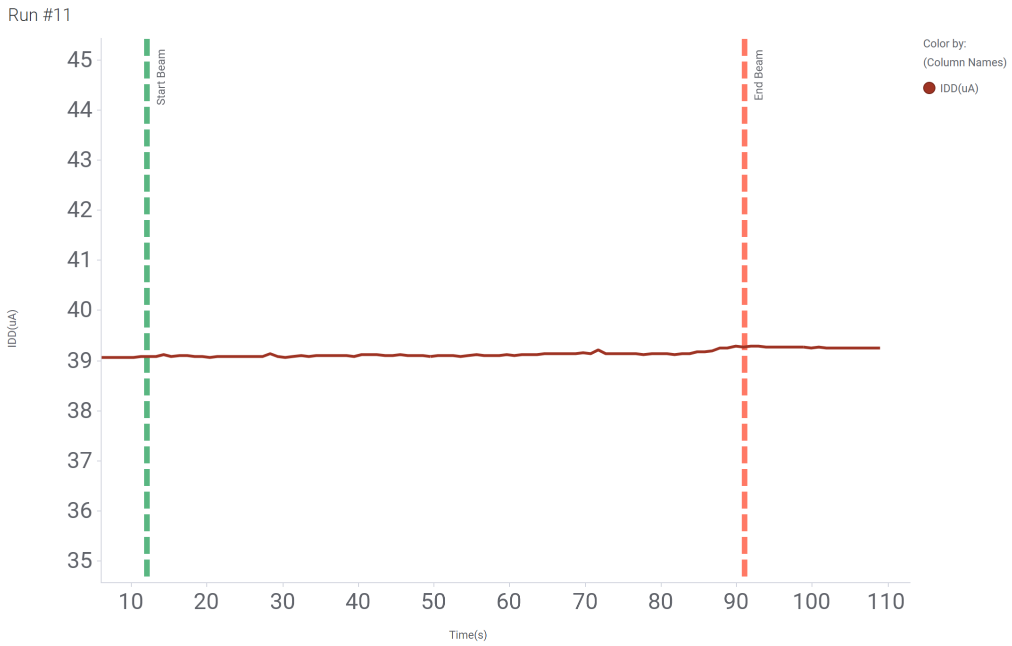


Figure 5-2. Current (µA) vs Time (s) for Run 11 of the TMUX182-SEP Bias 2 at T = 125°C

No SEL events were observed, indicating that the TMUX182-SEP is SEL-immune at LET_{EFF} = 47MeV-cm^2/mg and T = 125°C. Using the Mean-Fluence-To-Failure (MFTF) method shown in Single-Event Effects (SEE) Confidence Internal Calculations , the upper-bound cross section (using a 95% confidence level) is calculated as:

$$\sigma_{\text{SEL}} \leq 3.69 \times 10^{-8}\text{cm}^2/\text{device for LET}_{\text{EFF}} = 47\text{MeV} \cdot \text{cm}^2/\text{mg and T} = 125°\text{C} \quad (1)$$

5.2 Single-Event Transients (SET) Results

SETs are defined as heavy-ion-induced transient upsets on output pins D of the TMUX182-SEP. SET testing was performed at room temperature (no external temperature control applied). The species used for the SET testing was ^{109}Ag for a LET_{EFF} = 47MeV × cm^2/mg. Flux of approximately 1 × 10^5 ions/cm^2 × s and a fluence of approximately 1 × 10^7 ions/cm^2 were used for the SET runs.

One unit was tested across multiple input conditions to determine the worst-case setup for SETs. For Bias 1, one unit was powered up and exposed to the heavy-ions using supply voltage of 5V using a National Instruments PXI Chassis PXIe-4137. The bias was configured to select signal S7 as an output. A 0V to 1.8V, 1MHz square wave on input S7 was generated using a National Instruments PXI Chassis PXIe-5433 function generator. For Bias 2, one unit was powered up and exposed to the heavy-ions using supply voltage of ±5V using a National Instruments PXI Chassis PXIe-4137 and PXI Chassis PXIe-4139. The bias was configured to select signal S7 as an output. Pin S7 was connected to VDD. The run duration to achieve target fluence was approximately 100 seconds. Bias 1 showed transient upsets while Bias 2 showed no transient upsets, as listed in Table 5-3.

To capture SETs, one NI PXI-5110 scope card was used to continuously monitor the output voltage on pin D. The scope monitoring the square wave output signal was configured to a width pulse trigger of ±5%, while the scope monitoring the static output signal was configured to a voltage trigger of ±5%. The NI scopes were programmed to a sample rate of 100M samples per second (S/s) and recorded 1000 samples, with a 5% pretrigger reference, in case of an event (trigger). The setup was verified for each run to ensure no false triggers was captured before the beam was turned on. The ±5% threshold on the static and square wave outputs was determined to be the lowest threshold capable of not providing false triggers due to noise.

Under heavy-ions, the TMUX182-SEP exhibited transients on output D. The number of transients on each run are listed in Table 5-3.

Worst case transient are shown below. A few different types of transients are observed:

1. Signal Transient:
    a. Runt Trigger: Output shows signal distortion with periodic distorted pulses. Example shown in Figure 5-3. This example shows the maximum observed duration glitch with a duration of 4µs.
    b. Delayed Rising Edge: Output shows an extended low interval followed by a shortened high pulse causing a delayed rising edge. Example shown in Figure 5-4. This example shows the maximum duration observed was 1µs.

Table 5-3. Summary of TMUX182-SEP SET Test Condition and Results

Run Number	Unit Number	V_{DD}	V_{SS}	Ion	LET_{EFF} (MeV × cm^2/mg)	FLUX (ions × cm^2/ mg)	Fluence (Number ions)	Voltage Trigger	Width Trigger	SET Upsets (OUT)
21	4	5V	0V	Ag	47.5	1.00E+05	1.00E+07	N/A	5%	22
22	4	5V	-5V	Ag	47.5	1.00E+05	1.00E+07	5%	N/A	0

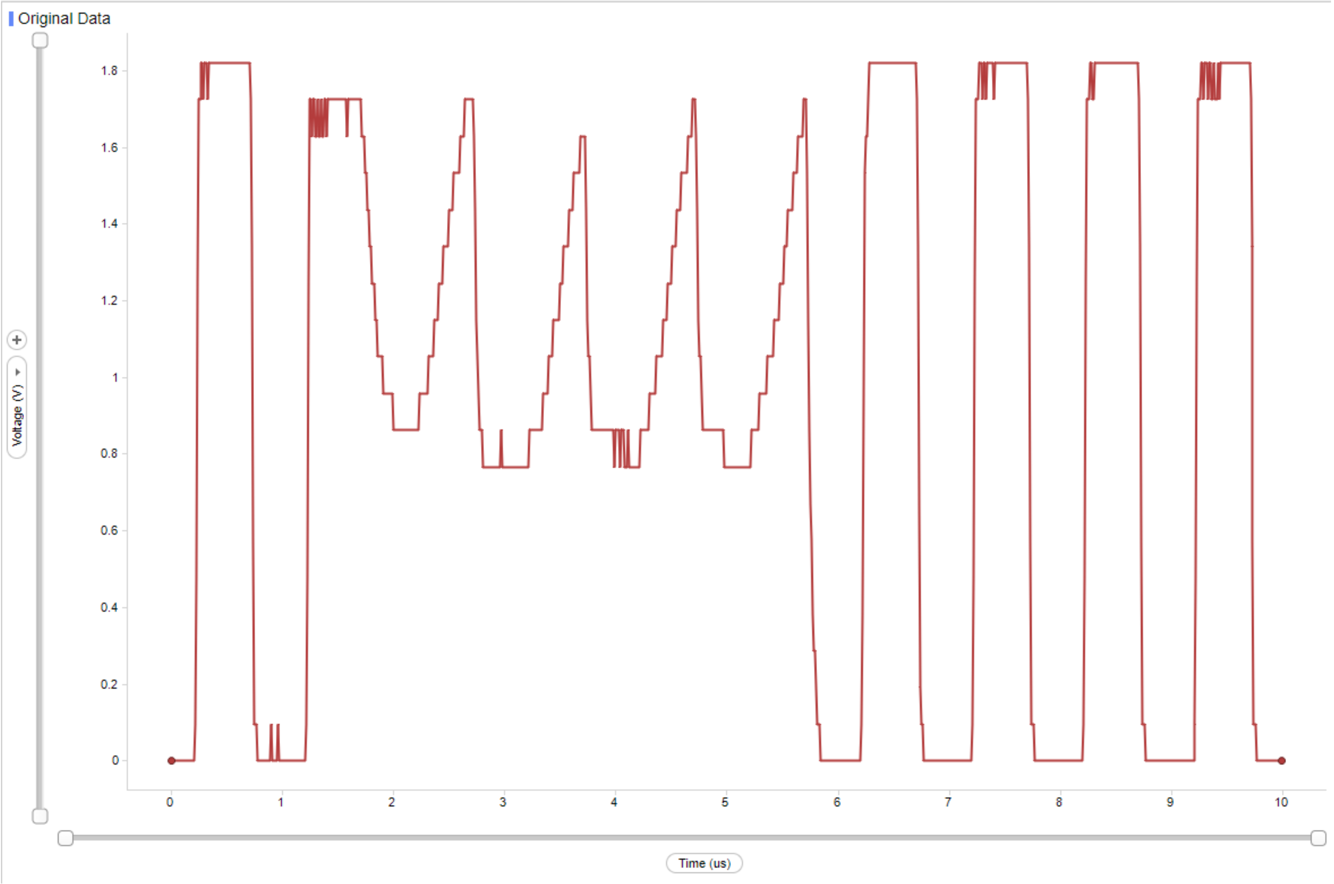


Figure 5-3. Single Event Transient on Dynamic Signal - Runt Trigger

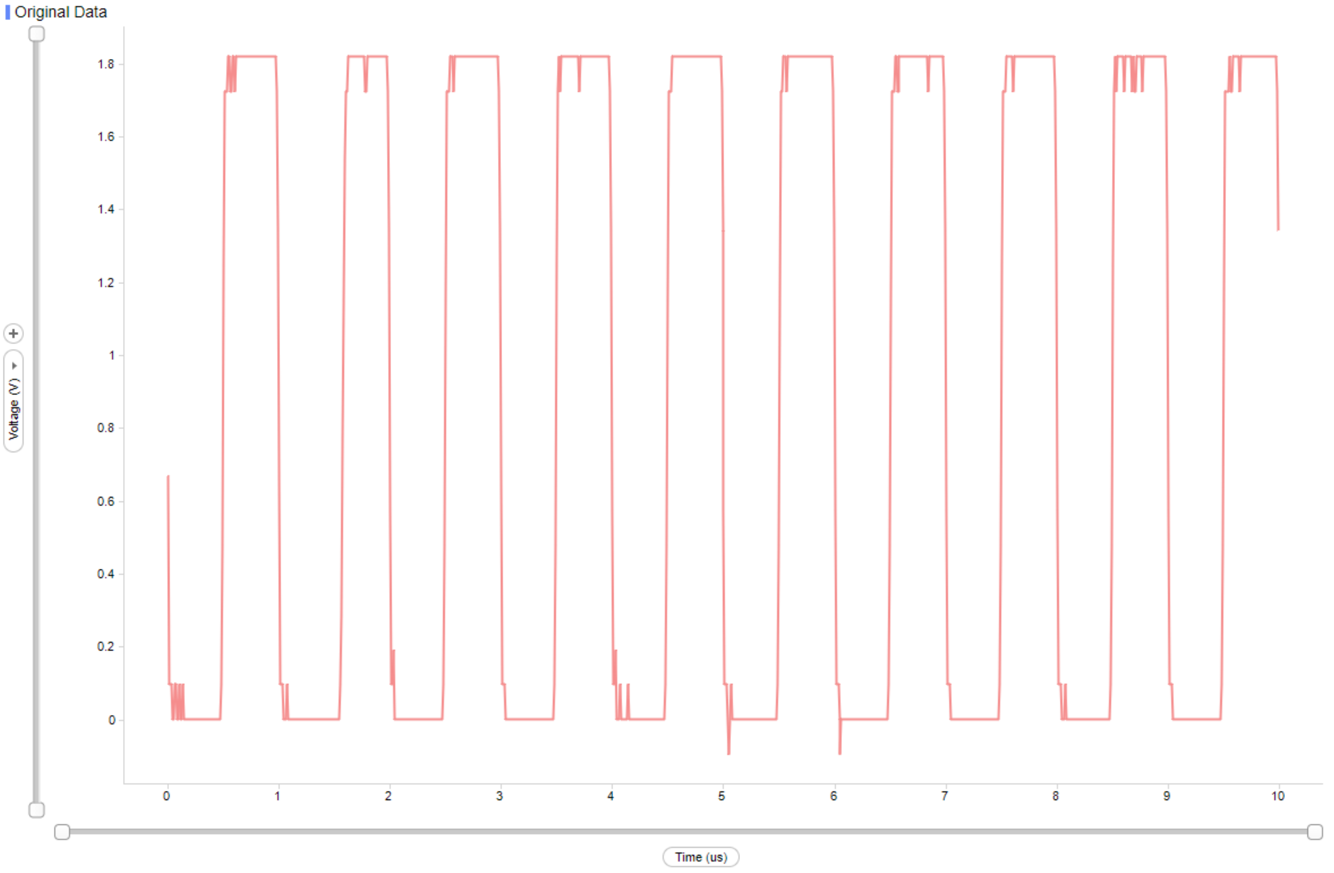


Figure 5-4. Single Event Transient on Dynamic Signal - Delayed Rising Edge

Using the MFTF method shown in Single-Event Effects (SEE) Confidence Internal Calculations, the upper-bound cross section (using a 95% confidence level) for Bias 1 dynamic outputs (D) is calculated as:

$$\sigma_{SET} \leq 3.33 \times 10^{-6} \text{cm}^2/\text{device for LET}_{EFF} = 47\text{MeV} \cdot \text{cm}^2/\text{mg and T} = 25°\text{C} \tag{2}$$

Using the MFTF method shown in Single-Event Effects (SEE) Confidence Internal Calculations, the upper-bound cross section (using a 95% confidence level) for Bias 2 static outputs (D) is calculated as:

$$\sigma_{SET} \leq 3.69 \times 10^{-7} \text{cm}^2/\text{device for LET}_{EFF} = 47\text{MeV} \cdot \text{cm}^2/\text{mg and T} = 25°\text{C} \tag{3}$$

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 TMUX182-SEP radiation-tolerant general purpose complementary metal-oxide semiconductor (CMOS) multiplexer (MUX). The device works with a single supply (5V to 15V), dual supplies (up to ±6V), or asymmetric supplies (such as VDD = 6V, VSS = –3V). The wide supply voltage range allows the devices to be used in a broad array of applications in space.

The TMUX182-SEP supports bidirectional analog signals on the source (Sx) and drain (Dx) pins ranging from VSS to VDD. All logic inputs have 1.8V logic compatible thresholds, which is compatible for both TTL and CMOS logic when operating with a valid supply voltage. SEE performance was verified at minimum (5V) and maximum (6V) for dual-rail operating condition and maximum (15V) for single-rail operating condition. Heavy-ions with an LET_{EFF} of 47MeV-cm^2/mg were used to irradiate five production devices with a fluence of 1×10^7 ions/cm^2. The results demonstrate that the TMUX182-SEP is SEL-free up to LET_{EFF} = 47MeV-cm^2/mg as 125°C. SET performance at 5V operating voltages saw excursions, as shown and discussed in this report.

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. Texas A&M University, *Texas A&M University Cyclotron Institute Radiation Effects Facility*, webpage.
4. James F. Ziegler, *The Stopping and Range of Ions in Matter (SRIM)*, 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.

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI’s products are provided subject to TI’s Terms of Sale, TI’s General Quality Guidelines, or other applicable terms available either on ti.com or provided in conjunction with such TI products. TI’s provision of these resources does not expand or otherwise alter TI’s applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025